

HUMAN-CENTERED
TECHNOLOGY TO
ENHANCE SAFETY
AND MOBILITY

INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE

2004-2005 ANNUAL REPORT

INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE

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A report of research, education, and technology transfer activities of the Intelligent Transportation Systems Institute at the University of Minnesota for fiscal year 2004–2005

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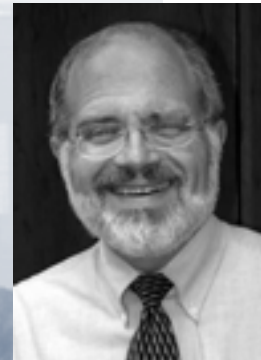
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UNIVERSITY OF MINNESOTA



CENTER FOR TRANSPORTATION STUDIES

Message from the Director



"The driver of a sport-utility vehicle loaded with teenagers lost control as it sped through a dangerous curve in Apple Valley early Tuesday. The vehicle rolled and at least two passengers were critically injured..."

The crash follows a pattern known by experts as the deadliest combination on the road: an inexperienced teen behind the wheel of a sport-utility vehicle, at night with a group of teenage passengers not wearing seat belts."

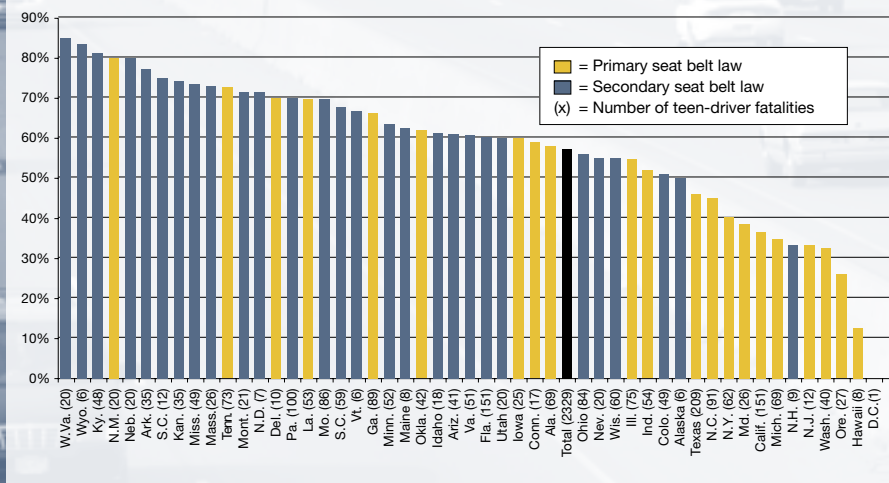
(from the Minneapolis Star Tribune, July 6, 2005)

Similar scenarios are all too familiar in most any part of the country. They illustrate the urgent need for new tools to reduce and prevent traffic fatalities. At the ITS Institute, we are doing our part.

Although our research often targets safety initiatives that help all drivers, several of our projects are focusing on specific high-risk groups. Our Intersection Decision Support work may prove most beneficial to elderly drivers, who have the most trouble determining when it is safe to pull out into faster-moving traffic. Other research is investigating the effects of sleep deprivation on drivers, such as commercial truckers, in order to prevent crashes caused by fatigue. And Professor Stephen Simon of the Law School, along with colleagues in the HumanFIRST Program and Intelligent Vehicles Laboratory, are investigating legal, technical, and behavioral approaches to reduce the incidence of teenage-driver crashes and fatalities.

I would like to focus for a moment on the issue of teen drivers, because this group has a higher fatality risk than any other driver age group on the road. Although teenagers (16–19 years old) make up less than 5 percent of all licensed drivers, they are involved in 13 percent of all fatal crashes. Approximately 6,000 teenagers are killed in motor vehicle crashes every year; this number has remained constant for over a decade, making automobile crashes the leading cause of death among this age group. New approaches to reduce teen fatalities are clearly needed.

Fig. 1. Unrestrained Teen-Driver Fatalities as Percent of Total Teen-Driver Fatalities (passenger vehicles only)
Source: FARS 2003



No doubt, many factors play a role, but one critical factor is seat belt use—or rather, the lack of it. Seat belt use remains lowest among teen drivers: 36 percent among fatally injured teen drivers, and 23 percent among fatally injured passengers (1995–2000). In Minnesota, over 60 percent of teen drivers killed on the road were *not* wearing their seat belts. Compare this to other states and to the country as a whole, as depicted in the accompanying graph (Fig. 1). Although the percentages may not be as compelling for states with lower teen-driver fatality numbers (since their relative ranking may not be statistically significant), it is surprising and of concern how high the rates are for states with high numbers of fatalities. Keep in mind that seat belt use for all Minnesotans was 79 percent in 2003, and 82 percent in 2004.

Studies have also shown that teenage passengers are even less likely to wear their seat belt when the driver is not buckled. Teen drivers are also less likely to wear their seat belt when alcohol is involved. These low use rates clearly contribute to the high level of fatalities associated with teen crashes.

The benefit of seat belt use is well known. The National Highway Traffic Safety Administration estimates that seat belts reduce the risk of fatality by as much as 45 percent for front seat occupants of passenger vehicles.

Seat belt “minder” systems have not solved the problem. Seat belt interlocks—devices that require drivers to engage their seat belts prior to starting the vehicle—should be implemented, at the very least, for teenage drivers. All vehicles currently manufactured contain much of the belt-fastening sensor technology necessary to implement a seat belt inter-

lock, and the costs are trivial for adding such functionality at the manufacturing stage.

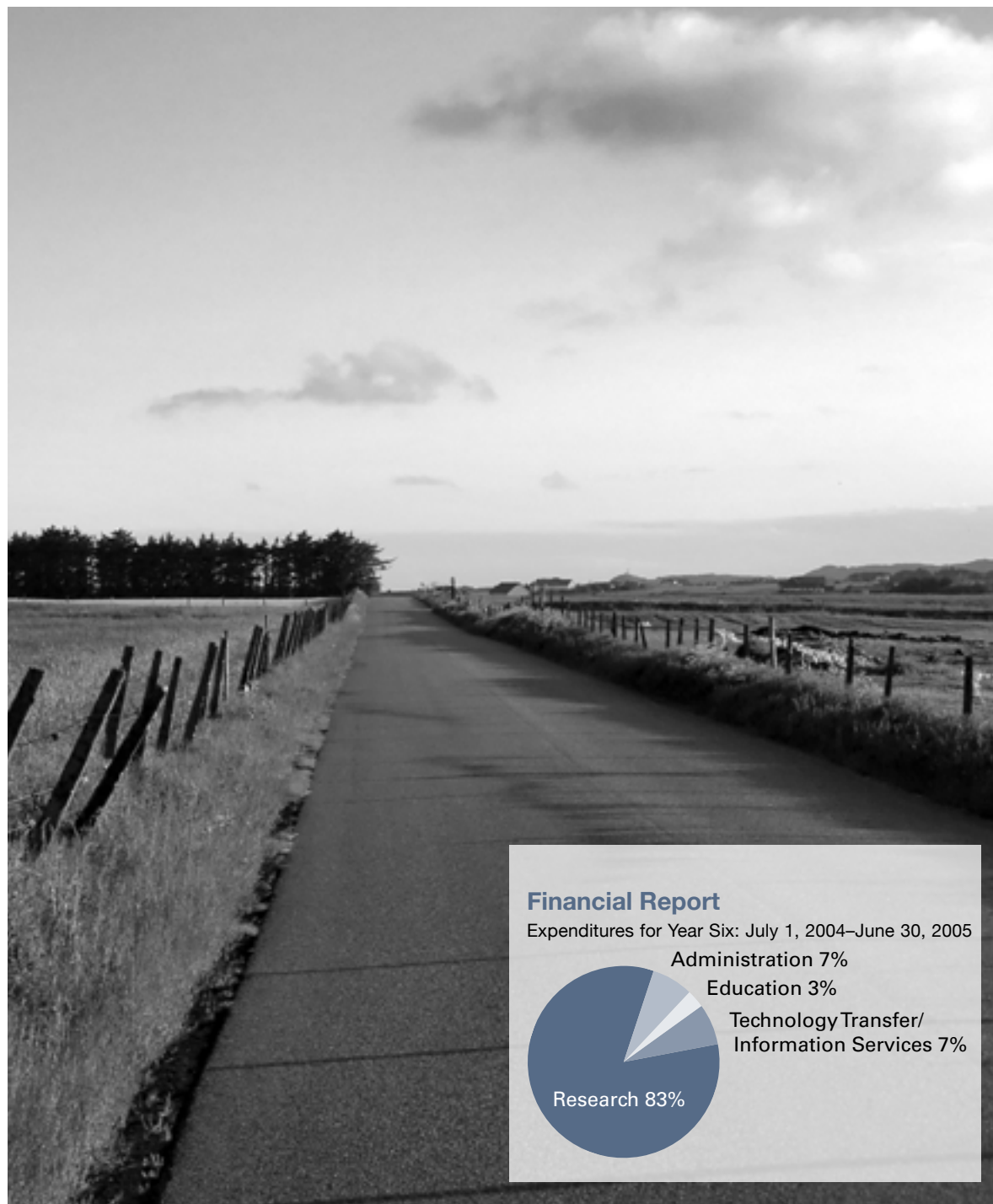
We realize there are legal, policy, and societal issues with these approaches—including past resistance from the public when they *were* implemented. That’s why researchers such as Simon and his colleagues in other departments are exploring this topic further. The message is simple: politics and inertia do affect the deployment of technology even when positive benefit-cost ratios can readily be demonstrated. We need to do more than simply pursue the research if we want to transform our results into practice. We will keep advocating for change.

Of the many different approaches Institute research may take, the goal is always the same: to improve the safety and mobility of transportation through a focus on human-centered technology. We will continue to foster our multidisciplinary group of researchers as they explore new ideas, and reach out to students and practitioners to inform and educate them about what is discovered. You can read about all our activities within this annual report.

We of course could not make any progress if not for the vital efforts of others. These include the members of our research selection and review panels and our board; our Institute staff, researchers, and students; the Minnesota Department of Transportation; the USDOT’s University Transportation Center Program in the Research and Innovative Technology Administration (RITA); and the taxpayers and their legislative representatives. Their belief in our mission and their support of our work is deeply appreciated, and for that we extend sincere thanks.



Although teenagers make up less than 5 percent of all licensed drivers, they are involved in 13 percent of all fatal crashes.



Mission Statement

The Intelligent Transportation Systems Institute is a congressionally designated University Transportation Center (UTC) funded through the Transportation Equity Act for the 21st Century (TEA-21), the federal transportation bill passed in 1998. This funding continues the Institute's efforts initiated under TEA-21's predecessor, the Intermodal Surface Transportation Efficiency Act of 1991.

The Institute plans and conducts activities that further the mission of the United States Department of Transportation's UTC program: to advance U.S. technology and expertise in the many disciplines that make up transportation through education, research, and technology transfer activities at university-based centers of excellence.

Our focus is human-centered technology that enhances the safety and mobility of road- and transit-based transportation. To that end, we direct the collective energies of researchers from multiple disciplines to advance the state of the art in the core ITS technologies of computing, sensing, communications, and control systems in order to surmount the significant transportation problems of the day.

Based on our theme, we bring together engineers and cognitive psychologists from the University with our partners—the USDOT, the Minnesota DOT, other government agencies, and private industry—to ensure that Institute-developed technologies become tools that help us understand and overcome human limitations as they relate to transportation.

Additionally, we address issues related to transportation in a northern climate, investigate technologies for improving the safety of travel in rural environments, and consider social and economic policy issues related to the deployment of core ITS technologies.

Management Structure

The ITS Institute is located on the Twin Cities campus of the University of Minnesota and is housed within the Center for Transportation Studies (CTS). Much of the Institute's successful leadership in the development and application of intelligent transportation systems and technologies results from its state and national partnerships, including those with CTS, the Minnesota Department of Transportation, private industry, and county and city engineers.

The Institute director leads the Institute's operation, implements its strategic plan, and assumes overall responsibility for its success. In this role, he directs Institute programs, personnel, and funds.

The Institute's board guides and oversees the implementation of the Institute's work. The board works with the director to ensure that the USDOT's Research and Innovative Technology Administration requirements are met, approves annual plans and budgets, and meets at least twice yearly to provide direction to, and approval of, the Institute's activities.

Institute staff and University researchers, drawing from various areas of expertise, help create and disseminate knowledge related to intelligent transportation systems through research, education, and technology transfer activities. In addition, the leadership and staff of CTS provide connections and access to an extensive transportation research and education network. The Institute's affiliation with the Center allows it to work seamlessly with CTS staff and benefit from its diverse outreach, administration, and communications capabilities.

Board members whose terms ended during the fiscal year:

Rebecca Brewster

President and Chief Operating Officer, American Transportation Research Institute

Ted Davis

Former Dean, Institute of Technology, University of Minnesota

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(Chair)
Director, Center for Transportation Studies



Vince Magnuson
Vice Chancellor for Academic Administration, University of Minnesota Duluth



Tom Sorel
Minnesota Division Administrator, Federal Highway Administration



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Dan Murray
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Northland Advanced Transportation Systems Research Laboratories

The NATSRL program director is James Riehl, dean of the College of Science and Engineering. Technical support is provided by Stanley Burns, professor and head, Department of Electrical and Computer Engineering (ECE); Donald Crouch, professor and head, Department of Computer Science; Taek Mu Kwon, professor, ECE; and David Wyrick, professor and head, Department of Mechanical and Industrial Engineering. Program management of NATSRL is provided by Carol Wolosz, with Jeanne Hartwick serving as the program accountant, David Keranen as the infrastructure engineer, and Ed Fleege as the research fellow.

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Mechanical and Industrial Engineering
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 David Wyrick

Natural Resources Research Institute
 Brian Brashaw



ITS Institute Laboratory and Facilities

ITS Laboratory

The Intelligent Transportation Systems (ITS) Laboratory is a dedicated facility supporting ITS research and education. The lab's mission is to develop and provide state-of-the-art resources for researchers, students, and collaborators pursuing research in ITS.

Focused on supporting research in surveillance, monitoring, and management of traffic systems, the ITS Laboratory works in partnership with other University of Minnesota research facilities including the HumanFIRST Program and the Intelligent Vehicles Laboratory to enable a full spectrum of ITS research.

The lab's facilities are used by faculty and students in civil, mechanical, and electrical engineering, computer science, and affiliated disciplines. The lab's data-gathering capabilities and modeling expertise serve as the foundation for the development of interactive laboratory modules to support ITS-related courses at the University. The lab also hosts training and outreach events.

The ITS Laboratory has developed several generations of data-acquisition systems to meet the needs of researchers working on freeway traffic-flow issues. The most recent of these is the Beholder system, a fully independent network of video detectors providing space- and time-continuous coverage of the I-35W/I-94 commons freeway area in Minneapolis.

Beholder expands on the pioneering Autoscope system, originally developed at the University of Minnesota and now in commercial use. Beholder's portable monitoring stations are currently deployed on the roofs of several high-rise buildings overlooking the freeway, and transmit data back to the lab via a high-speed IEEE 802.16 wireless network.

Besides the data provided by the Beholder system, the lab is supplied with eight switchable compressed/streamed Internet video feeds by the Minnesota Department of Transportation (Mn/DOT). Researchers have the ability to switch

Left: The Virtual Environment for Surface Transportation Research (VESTR) driving simulator

between any of the approximately 300 Mn/DOT cameras monitoring the metropolitan freeway network.

Several traffic simulation packages are used in the ITS Laboratory, chiefly AIMSUN2 for microscopic flow simulation based on individual vehicles, and the KRONOS 9 package—developed at the ITS Institute—for macroscopic or platoon-based simulations. Other packages such as Vis-Sim are used as needed.

Recent simulation and modeling projects at the ITS Laboratory have focused on improving the efficiency of metered access to urban freeway networks and on developing a dynamic, centrally regulated traffic signal preemption system for emergency vehicles.

Putting the researcher inside the simulation is the goal of the ITS Laboratory's Digital Immersive Environment, or DEN. Three large rear-projection screens surround the user; behind the scenes, a bank of six computers controls a visual environment developed using Open Scene Graph (OSG) and driven by data from an AIMSUN2 traffic simulator.

Each screen displays both left- and right-eye projections simultaneously, and polarized eyeglasses fuse the image channels to create a three-dimensional virtual world where the corners of the DEN melt away. Users can navigate and interact with the simulated world using a handheld wand; a high-accuracy tracking system constantly adjusts the

Around 70 undergrads at the University of Minnesota will control stoplights on Washington Ave. S.E. for a few weeks each semester, but don't get too worried—it's only a simulation. A Web-based traffic control simulator designed by ITS Senior Systems Engineer Chen-Fu Liao is being used to teach civil engineering students in an introductory transportation engineering course how to optimize traffic flow at intersections, from their home computers if they choose.

The interactive lab module, designed to meet the needs of civil engineering educators, is the second traffic control lab module Liao has developed in the ITS Lab. It is a vast improvement over the first, a static lab module featuring only 12 pre-planned scenarios. The second version allows users, via four AIMSUN nodes located in the ITS Lab, to change several variables of a four-way intersection: traffic demands, turning proportions, and timing of

the signals. This creates "an infinite number of possible situations," said Liao. Users can also track individual vehicles, visualize congestion, and view any point within the simulated time range to observe traffic conditions in the two-dimensional Java interface—three advantages of the simulator, which supplements classroom lectures and formulas on paper.

Senior Michael LaCasse, an Institute of Technology student in the transportation engineering class that used Liao's simulator, said he was quickly aware of these advantages when traffic conditions in an intersection did not match his expectations. "With the simulator I could quickly see what was happening," he said. "If all I had was data output in a listing... I would have wondered why the traffic signal did not perform similar to my mathematical calculations," said LaCasse.

Another advantage of this simulator over previous methods of instruction is the variable

speed allowed by the AIMSUN nodes. When a scenario is created, the user can not only view the traffic conditions at a one-to-one speed (also known as "real-time"), but at any desired speed. The key to this is to have the AIMSUN nodes process the scenario entirely, then send the packet to the remote user. The user may then select any time within the simulation and view the traffic data at that point. This also frees up the nodes to process other simulations, allowing many people to use the program at the same time—people, Liao says, he hopes will one day include lawmakers, researchers, and the general public.



The Java-based user interface for the Web-based traffic simulation module. Students can select a vehicle and monitor the distance traveled on the time-space diagram overlaid with the signal phases along the corridor.

The University of Minnesota is recognized as a leader in developing and testing driver-assistive systems.

perspective of the projected scene according to the position and orientation of the user's head.

The DEN can help investigators understand traffic flow within the context of urban design constraints, pedestrian uses, and other factors that have been impossible to visualize using conventional display technologies. It also complements the vehicle simulation capabilities of the Human-FIRST Program, including the ability to use the same virtual worlds in both environments.

Intelligent Vehicles Laboratory

The Institute's Intelligent Vehicles Laboratory focuses on developing and testing innovative, human-centered technologies that improve the operational safety, mobility, and productivity of vehicles. These human-centered

technologies integrate sensors, actuators, computer processors, and custom human interfaces to provide drivers with needed information under difficult driving conditions, including low visibility, severe weather, and narrow and congested roadways. Initially, these driver-assistive systems have been tested on specialty vehicles, including snowplows, patrol cars, ambulances, heavy vehicles, and transit vehicles. Ultimately, these systems will also be used on passenger vehicles, providing drivers with warnings and assistance with collision-avoidance and lane-keeping tasks.

The University of Minnesota is recognized as a leader in developing and testing driver-assistive systems and is one of a small number of universities nationwide conducting this work. The IV Laboratory's core staff consists of engineering professionals who work closely with an interdisciplinary

team of specialists, including cognitive psychologists specializing in human factors from the ITS Institute's Human-FIRST Program. The IV Laboratory staff has developed expertise in wireless communications, embedded computing, visibility measurement and quantification, geospatial databases, virtual environments, image processing, driver-assistive technologies, control systems, and sensors.

IV Laboratory research seeks to increase driver safety in difficult driving conditions through the use of vehicle-guidance and collision-avoidance technologies. Several vehicles serve as experimental testbeds, including the SAFETRUCK (an International 9400 tractor-trailer), the SAFEFLOW (an International 2540 crew-cab snowplow), a state highway patrol car, and the TechnoBus (a Metro Transit



IV Lab researchers at the site of the Intersection Decision Support system prototype include Alec Gorjestani, program director Craig Shankwitz, Bryan Newstrom, Pi-Ming Cheng, Lee Alexander, and Arvind Menon

bus). Using these vehicles, IV Laboratory researchers are developing, testing, and integrating advanced technologies including centimeter-level differential global positioning systems (DGPS); high-accuracy digital-mapping systems; range sensors, including radar and laser-based sensors; a windshield head-up display (HUD), a virtual mirror, and other graphical displays; as well as haptic and tactile feedback.

The IV Laboratory's lane-assist technology is unique in that it uses DGPS and does not require hardware in the roadway surface. The technology is transferable between various transportation modes and works in all low-visibility situations, including snow, fog, smoke, heavy rain, and darkness. In addition, these systems use human-centered technologies to enhance driving ability and reduce driver

error due to distractions, fatigue, and other factors related to difficult driving situations.

Other difficult driving conditions are encountered by drivers on a daily basis. For instance, the vast majority of vehicle crashes occurring at rural, unsignalized intersections are the result of drivers incorrectly gauging the size of a gap between oncoming vehicles, not running stop signs. The IV Lab has developed a sophisticated rural intersection data collection system used to study how drivers waiting at a low-volume minor road enter or cross a high-speed, high-volume expressway. The data collected at the intersection will be used to model driver behavior to determine where the gap-acceptance decision-process fails and leads to a crash, and to then design countermeasures to reduce the number of these crashes.

Additional research topics include the design and testing

of custom human interfaces, collision-avoidance sensors and algorithms, and wireless communication among vehicles and with the infrastructure. The IV Laboratory's partnership with the Minnesota Department of Transportation provides access to roads and other infrastructure, including the Minnesota Road Research Project (Mn/ROAD) test track, which consists of a freeway and a low-volume road pavement test track with 40 different road material test sections, 4,500 electronic sensors, a weigh-in-motion scale, a weather station, and DGPS correction signals. The IV Laboratory also has relationships with a number of other organizations and government agencies, including the U.S. Department of Transportation's Research and Innovative Technology Administration, Federal Highway Administration, and Federal Transit Administration; Twin Cities' Metro Transit; Minnesota's Local Road Research Board;

Lee Alexander, research fellow with the University of Minnesota's Department of Mechanical Engineering, hopes that in the summer of 2005, he'll draw the short straw. If so, he'll get to be the first member of the research team to drive the machine it has spent nearly four years developing: a three-wheeled, commuter-focused, narrow tilting vehicle (NTV) that could double the capacity of our congested roadways and get gas mileage on par with most motorcycles.

Reducing road congestion requires either more roads or fewer cars. The NTV project, also supported with funds from the National Science Foundation, aims to reduce congestion with a vehicle smaller than what is commonly driven today. The design is strongly inspired by motorcycles: for safety and vision purposes, it is as tall as a car, but about half

as wide, allowing two vehicles to occupy the same lane. This effectively doubles the capacity of roadways without requiring costly infrastructure changes, like the construction of new roads.

The research team, made up of mechanical engineering professors Rajesh Rajamani and Patrick Starr, graduate student Sam Kidane, and Alexander, decided that the NTV's two front wheels and single rear-wheel platform would grant more balance, stability, and power than a two-wheeled model. Because of its narrow wheelbase and high center of gravity, the vehicle would be prone to rollovers while turning at

highway speeds without the ability to lean into turns. The centerpiece of the project, a lateral stability system, solves this problem. A frame-mounted computer controls motors that automatically countersteer and tilt the vehicle in the appropriate direction when turning, like

a rider would lean a motorcycle. The main goal of the project is to "have the vehicle do the balancing so the drivers can just steer in the direction they want to go, rather than have to balance and steer like a motorcyclist has to do,"

said Alexander. The NTV is expected to be as agile as wide-body vehicles, according to Alexander, but snow and ice traction issues are still being worked

out.

With one less wheel and a fraction of the weight of a standard car, the NTV will also be a highly fuel-efficient vehicle, equipped with a low displacement engine capable of speeds up to 70 mph.

Alexander noted that the control system was the present priority, and that safety features would be worked out when the vehicle is closer to public use. "Safety is always a concern," he said, listing the safety features to be integrated as the vehicle approaches production: an integral roll cage, a seat belt/shoulder harness system, and an energy-absorbing crushable structure to protect the occupant in the event of a collision.



is-



HumanFirst researchers. Back row: Mike Manser, Peter Easterlund, program director Nic Ward, and Mick Rakauskas. Front row: Gerald Cowart, Janet Creaser, and Praveen Balachandran

and various counties. These partnerships provide additional support for implementing research that will influence transportation safety in the United States and around the world.

Human Factors Interdisciplinary Research in Simulation and Transportation

The mission of the Human Factors Interdisciplinary Research in Simulation and Transportation (HumanFIRST) Program is to apply human factors principles in order to understand driver behavior and support the design and evaluation of usable intelligent transportation systems. As implied by its name, the program's research strategy is based on a driver-centered approach, considering the "human first" within the transportation system.

The HumanFIRST Program has a core staff of transportation research specialists made up of psychologists and engineers who provide a consistently available base of expertise. This core group is linked to a broad interdisciplinary network of experts in basic and applied sciences throughout the University to provide a flexible and comprehensive research capacity. This network is supported by affiliations with additional University research units, which allows the program to create responsive interdisciplinary teams to investigate a range of complex human factors research issues in transportation safety. The program also has close relationships with the Minnesota Department of Transportation and the Department of Public Safety, private industry, traffic engineering consultants, and other related entities. These connections provide support for imple-

Testing new methods for improving traffic safety is essential in order to learn how well they will perform. However, testing that begins in the controlled conditions of laboratories and driving simulators often cannot be reliably replicated in more natural, "real-world" test environments.

This led the HumanFIRST Program to develop a new method to transfer controlled simulator scenarios to test-track and field studies. One component is an instrumented lead vehicle fitted with DGPS and operating within a digital map generated for the test environment. This vehicle is linked by wireless communication and DGPS to a test vehicle. Onboard computers produce specific driving scenarios, which can be the same as those used in the driving simulator, as both are programmed with the same control logic.

In this application, a prior simulator study examined driver response in a rear-end crash

scenario during which the driver of the following car was distracted with a secondary task. This involved linking an eye tracker and the secondary task to the simulator in order to automatically trigger the car-following scenario when distraction was detected. The lead vehicle would follow a specified speed profile and then "hunt" for the subject in the following car to move within a defined range of headway (to create a desired hazard level). When the eye tracker detected that the driver was distracted with the secondary task, a trigger would result in the lead vehicle braking with a specified deceleration rate.

In the test track study, the test vehicle was also equipped with an eye tracker and the secondary task. The gaze direction of the driver and interaction with the secondary task was again used to define distraction. The onboard computer, linked to the control actuators of the lead vehicle, was programmed

to autonomously create a similar speed profile as used in the simulator study. The driver of the lead vehicle needed only to steer, since the parameters of all events were controlled precisely by the computer control system.

At a determined point in the scenario, the lead vehicle would hunt for the test vehicle and also monitor the output from the eye tracker and secondary task. As soon as the driver was distracted, the lead vehicle executed its specified scenario-braking event. By virtue of the DGPS and digital map, the test vehicle recorded the same types of data as the simulator with comparable levels of reliability.

The second component of this method is a virtual "safety net." The researchers developed an algorithm to automatically trigger evasive acceleration in the lead vehicle and braking in the test vehicle if the headway was detected to move into a specified hazard region. In

addition, a "watch dog" system continuously monitored the safety-critical components of the integrated system, and, if it detected failure, the system alerted the drivers and stopped both vehicles.

The combination of the automated lead vehicle and safety net provides a way to translate scenarios from a driving simulator to real-world conditions with the same level of data reliability and control without risking safety. Conversely, this system allows the researchers to replicate test track infrastructure perfectly within the simulated environment. Moreover, the use of the safety net extends the range of risk that can be developed in the test scenarios.

menting research that will influence transportation policy in response to real-world problems both regionally and nationally. In addition, to ensure that research takes into account developments on the world stage, the program's work is supported by international collaborations with experts in relevant disciplines.

Research in the HumanFIRST Program seeks to propose, design, and evaluate innovative methods to improve transportation safety based on a scientific understanding of driver performance and the psychological processes associated with traffic crashes. This research considers how a driver will accept and use a proposed system, while also considering the possibility of its producing undesirable driver responses and adaptation (e.g., distraction, complacency, fatigue, risk taking) that could undermine the system goal of improved safety.

Recent research topics include:

- driver distraction from in-vehicle tasks and cell phones
- rural and urban driver attitudes and crash risk
- interventions for crash reduction at rural intersections
- bus rapid transit using dedicated narrow shoulders
- driver fatigue and methods for its detection
- intelligent driver-support systems such as vision-enhancement, collision-avoidance, hazard-awareness, and lane-keeping systems for passenger and specialty-purpose vehicles
- learned and inherited factors related to unsafe driving
- alcohol impairment
- attention-deficit/hyperactivity disorder and novice drivers
- in-vehicle use of Advanced Traveler Information Systems (ATIS)

The facility includes equipment for basic research on driver psychological functioning including a vision tester, DOT-certified alcohol Breathalyzer, mobile psychophysiology recording system, mobile eye-tracking system, video editing and behavior analysis suite, and a comprehensive psychometric test battery validated for traffic psychology.

Much of the research of the HumanFIRST Program uses a state-of-the-art driving simulator (supplied by AutoSIM and OKTAL) engineered specifically for human factors research in surface transportation. This Virtual Environment for Surface Transportation Research (VESTR) is a versatile and realistic simulation environment linked to a full-cab SC2 vehicle donated by Saturn using software that can create virtual environments that precisely reproduce any geospecific location. This visual environment is generated with high-resolution images (2.5 arcmin per pixel) over a wide field of view (210-degree forward, 50-degree rear, 2 by 20-degree side mirror images). This immersive driving experience is enhanced by realistic motion generated by a three-axis motion base and both high- and low-frequency vibration units, including a surround-sound system. With multiple sound systems, configurable touch panel displays (including head-up displays), haptic feedback through the seat and accelerator pedal, and a head-free eye-tracker that can detect in real time what a driver is looking at, this simulator supports the investigation of a wide range of interface options for ITS development, design, and assessment. These features make VESTR one of the premier driving simulators in North America and Europe.

To support the validity of HumanFIRST research, the program has access to a variety of closed test tracks and road network field sites for on-road studies with instrumented vehicles.

Northland Advanced Transportation Systems Research Laboratories

The Northland Advanced Transportation Systems Research Laboratories (NATSRL) is located at the University of Minnesota Duluth. Its mission is to study comprehensive winter transportation systems and the transportation needs of cities in small urban areas. To accomplish this, NATSRL collaborates with the Minnesota Department of Transportation, city and county engineers, and other agencies on research that covers a wide range of topics, including opti-



NATSRL researcher Stan Burns and program director James Riehl



An RTMS sensor monitors traffic on Highway 35 in Duluth. NATSRL researcher Taek Kwon is using it to integrate traffic data with R/WIS for analysis and archiving.

cal and electronic traffic and road sensors, transportation data management, and benchmarking of transportation infrastructure.

NATSRL's current laboratories are the Advanced Sensor Research Laboratory, the Transportation Data Research Laboratory, and the Transportation Engineering Research Laboratory. The Advanced Sensor Research Laboratory tests advanced sensing technologies for pavement and road conditions (speed, weather impact, and traffic density), researches the development of new techniques to detect incidents and abnormal traffic conditions, and analyzes real-world and real-time measurements of road, weather, and traffic information. The Transportation Data Research Laboratory has developed a statewide traffic data archival and analysis system that is used by Mn/DOT for long-range

planning and the development of strategic traffic management plans, and continues research in the improvement of data integrity retrieved from the road sensors. The Transportation Engineering Research Laboratory is developing, in conjunction with Mn/DOT, an automated inventory management system for transportation infrastructure and the design of efficient management practices through benchmarking state DOT procedures.

Other NATSRL projects include developing a traffic counter for low-volume roads and student development of software tools to manage large volumes of transportation-related data.

In addition, NATSRL partners with Mn/DOT District One each year to provide a day-long formal presentation of ongoing research efforts.

Determining an optimal time to replace snowplows and other fleet assets could save state transportation departments a significant amount of money: replacing too early requires a great deal of capital and replacing too late results in extra maintenance and operations costs for older trucks. In addition, life-cycle times affect the economics and deployment of new vehicle technologies.

In a recent research study conducted through NATSRL, David Wyrick, professor and head of the Department of Mechanical and Industrial Engineering at the University of Minnesota Duluth, set out to investigate how to improve fleet operating costs through effective vehicle replacement, to validate (or challenge) the current vehicle life standard of 12 years, and to understand utilization issues at the Minnesota Department of Transportation (Mn/DOT).

Wyrick used the Equivalent Uniform An-

nual Cost (EUAC) method as one way to determine an appropriate life-cycle standard for Mn/DOT's fleet, focusing on the class 330 snowplow. This method analyzes the costs associated with owning a fleet asset throughout its life to reveal the time range with the lowest annualized costs. Over the life of a vehicle, the annualized acquisition cost comes down as the annual operating costs go up. Using EUAC, the researcher looks for the area in the middle after the acquisition cost has gone down enough and before the operating costs have gone up too high. This is the "window of opportunity" for replac-

ing assets, Wyrick says.

Good data were hard to find because of inconsistent entering and tracking of data, but Wyrick was able to make some tentative conclusions based on his analysis. He provided examples from two Mn/DOT districts: District 6, in the southeast corner of the state, and District 1, in the north. The results showed

an average optimal life cycle of 10.76 years for District 6, and 9.26 years for

District 1. Assuming the results can be generalized, if the life cycles of Mn/DOT's snowplows were reduced from 12 years to 8 years, Mn/DOT could save up to \$330,000 per

year statewide on the class 330 snowplows alone.

However, Wyrick says that a statewide life-cycle standard "may not be optimal" because of differences among districts and among individual vehicles. He suggests that life-cycle analysis could be conducted on an individual unit basis to dispose of problem vehicles earlier and to keep reliable vehicles longer. This could be done by using trend analysis, which tracks whether the cost is increasing or decreasing for each vehicle and then replacing those for which the costs are increasing, or by using a control chart, which tries to keep costs between specified upper and lower limits.

[The final report of this research is available at www.its.umn.edu/research/complete.html.]

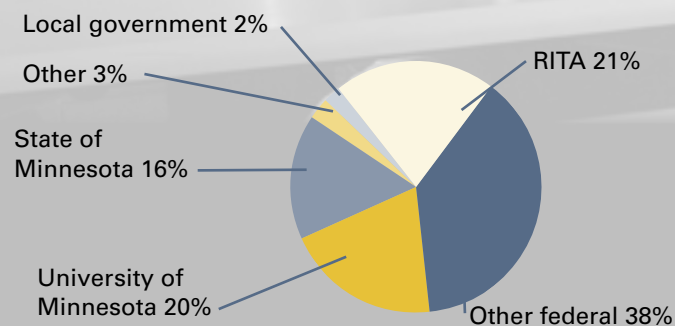






Research funding sources for all ITS-related research projects

The total funding for all ITS-related research projects was more than \$6.3 million in FY05. Sources for projects receiving funding in FY05 are shown in the chart at right.



RESEARCH

Institute research is centered on safety-critical technologies and systems for efficiently moving people and goods in the following areas:

- human performance and behavior
- technologies for modeling, managing, and operating transportation systems
- computing, sensing, communications, and control systems
- social and economic policy issues related to ITS technologies

The Institute's research program joins technologists—for example, engineers and computer scientists—with those who study human behavior to ensure that new technologies adapt to human capabilities, rather than requiring people to adapt to technology.

The Institute's geographic location gives it a unique advantage for developing research applicable to transportation in a northern climate and transportation in rural environments in addition to the metropolitan Twin Cities area. The ITS Institute research program includes research projects funded by various partners, including federal funds from TEA-21 legislation, the Federal Highway Administration, and the Federal Transit Administration. Other funding partners include the Minnesota Department of Transportation (Mn/DOT), the Minnesota Local Road Research Board, and Metro Transit, in addition to local governments, agencies, and private companies that contribute funding and in-kind match.

Activities undertaken by the Institute support all ITS-related research projects, regardless of funding source; all current ITS-related projects are listed in this annual report. The research section comprises two parts. The first highlights in detail a selection of projects underway, while the second briefly describes other Institute projects either recently completed, in progress, or selected to begin this coming year.

In back: Captain Ken Urquhart and Officer Wes Pemble of the Minnesota State Patrol-Commercial Vehicle Section, who served as technical advisors for a sleep-deprivation research project. In front: research associates Kathleen Harder and John Bloomfield and research assistant Ben Chihak

Human Performance and Behavior

Fatigue, Sleep Deprivation, and Driving Performance

A century ago when sleep schedules generally followed the sun's schedule, the average person slept about nine hours a night. Fast-forward to the mid 1970s and this number falls to about seven-and-a-half hours. And today, nearly one-third of Americans get less than six hours of sleep every night. Chronic sleep deprivation can cause a variety of physical and psychological problems, which can be especially dangerous when someone suffering them gets behind the wheel of a vehicle. National Highway Traffic Safety Administration data conservatively estimate that 100,000 police-reported crashes are the direct result of driver fatigue each year, and these crashes cause an estimated 1,550 deaths and 71,000 injuries.

In light of such statistics, researchers from the College of Architecture and Landscape Architecture are investigating the effect of sleep deprivation on the driving performance of commercial motor vehicle (CMV) drivers. Dr. John Bloomfield, the study's principal investigator, agrees that driver fatigue is an important causal factor in many of the crashes that occur annually on highways in the United States. This is particularly true in the trucking industry, where many operators undertake long-haul drives with limited sleep.

Fatigue, which is a subjective state that can be defined as physical or mental weariness sufficient to impair performance, is clearly related to sleep deprivation. In this study, Bloomfield used an advanced driving simulator to explore the relationship between sleep deprivation and various aspects of driving performance, and also to determine whether or not there are correlations between sleep deprivation, driving performance, and data obtained from fatigue-detection devices. Although many researchers are

interested in fatigue, Bloomfield says, very few studies have actually explored the effects of sleep deprivation on driving performance in a controlled setting like that provided by the driving simulator.

With help from the Minnesota Trucking Association, 20 CMV drivers were recruited to participate in the study. Each took part in an experimental session lasting 20 hours. During each experiment, the driver, who was kept awake throughout the session, "drove" in the driving simulator on four occasions. The first drive began

at 9 a.m., the second at 3 p.m., the third at 9 p.m., and the fourth at 3 a.m. After participating in the 20-hour session, each driver was taken to the University's General Clinical Research Center (GCRC), where he or she was able to sleep for at least eight hours.

The simulator vehicle used in the study was a full-sized Saturn coupe; when seated in this vehicle, the driver had a 210-degree forward field-of-view, and rear-view imagery provided via a 10-foot by 7.5-foot screen behind the vehicle and LCD screens installed in place of the side-view mirrors. Each drive—over flat, featureless terrain—was 60 miles long, during which the driver covered 46 miles of divided highway, 12 miles of two-lane bi-directional road, and finally, 2 more miles of divided highway. The driver passed through several intersections on the route and encountered low traffic levels. In addition to collecting driving performance data throughout each drive, Bloomfield, along with co-principal investigator Dr. Kathleen Harder and research assistant Ben Chihak, assessed driver impairment using several test instruments including the EyeCheck™ pupilometer, an instrument that measures pupil dynamics; the psychomotor vigilance test (PVT), a well-validated test of behavioral alertness; and the code substitution test, a measure of cognitive function.

Each year, 100,000 police-reported crashes are the direct result of driver fatigue, and these crashes cause an estimated 1,550 deaths and 71,000 injuries.



The team is now analyzing the study results. Initial findings reveal that between the first drive and the fourth, drivers showed a significant increase in steering instability. This indicates that drivers' steering performance was impaired during their last drive between 3 a.m. and 4 a.m. However, there were no other significant differences in driving behaviors, such as average driving speed and stopping behavior, between the first and fourth drives.

There does not appear to be a relationship between the impairments that were found in steering control and the data obtained with the EyeCheck pupillometer or other test instruments. This is unfortunate, Bloomfield says. If reliable relationships between driving performance impairment and the fatigue detection devices tested in this study had been found, those devices might have been used by law enforcement officers. The devices, along with the fatigue driving evaluation checklist recently developed by the Minnesota State Patrol, could have been used to test fatigue levels in truck drivers in efforts to keep them, and all drivers on U.S. roadways, safer.

Design and Safety Implications for ATIS Use with Cell Phones

Distracted driving—whether the result of cell phones, the car stereo, or any number of other factors—is assumed to be more dangerous driving. Now an Institute study has found that using a cell phone may impair drivers more than



alcohol intoxication. The research, led by Nic Ward, director of the Institute's HumanFIRST Program, assessed the risk of cell phone use while driving compared to commonly accepted in-vehicle tasks, as well as driving while intoxicated.

The study included the work of HumanFIRST research scientist Mick Rakauskas along with Ed Bernat,

Meredith Cadwallader, and Professor Chris Patrick of the University of Minnesota's Department of Psychology.

Because evidence suggests that cell-phone use while driving may be a significant risk factor in traffic crashes, some states have responded by imposing restrictions on the use of hand-held phones. But Ward's research team, citing research that shows hands-free use is no safer than hand-held, has focused instead on the cognitive aspect of talking on a cell phone while driving. "It's actually the conversational component of operating a cell phone while driving that is the culprit," Ward says, "not just the physical manipulation of the phone."

In particular, the two-part study is probing the risks of using cell phones to access new advanced traveler-information systems (ATIS) recently introduced in many states (e.g., 511 Traveler Information Services). Phase I of the study examined how the performance impairment from cell-phone use compares to other types of impairment risks, such as driving while intoxicated (.08 blood-alcohol content) and while operating common in-vehicle controls like a radio, fan, or air conditioning. For the first time, research-

ers also examined the combined effects of being distracted and being intoxicated, given that many crashes result from a combination of risk factors. Phase II will examine the design of 511 services in order to make them less distracting for drivers.

Ward explains that use of a cell phone and other typical in-vehicle tasks are considered secondary to the primary tasks of driving and driving safely. Previous studies have shown that the increased mental demand of cell-phone use causes impairment—and an increased crash risk. By Ward's definition, impairment means exceeding the limit of one's ability to apply the necessary resources toward a particular task. When that task is driving, impairment may, for example, cause speed inconsistency and slower reaction toward unexpected events. "The brain is dulled because of the secondary task," Ward says.

In their experiments, the researchers gathered data from test subjects outfitted with a device to measure brain activity and using the Virtual Environment for Surface Transportation Research (VESTR) driving simulator in the HumanFIRST lab. Half the test subjects drank alcohol to near intoxicating levels (just under .08 blood-alcohol content) as measured with a Breathalyzer.

Participants drove normally along a simulated rural route and were exposed to a variety of traffic interactions. Driver impairment was measured in terms of subjective (how difficult they thought driving was), behavioral (how they handled their vehicle), physiological (how their mind and body reacted), environmental awareness (how aware they were of their surroundings), and Breathalyzer measures.

Drivers completing either cell-phone or in-vehicle tasks during a car-following scenario showed worse performance than those driving without a task in terms of time headway, maintaining a consistent speed profile with respect to the lead vehicle, and steering. And, Ward says, "The drunk driver doing nothing but driving was less impaired than the sober drivers on a cell phone or playing with the radio."

Measurements of brain activity showed that drivers who

were engaged in secondary tasks were less attentive and mindful of unexpected events. Drivers conversing on the cell phone and completing in-vehicle tasks while sober had lower accuracy during a target-tone task (in which they listened to a sequence of tones and responded to a particular tone via a left-foot pedal) than intoxicated drivers not completing any secondary task. And during an environmental awareness task, both cell phone and in-vehicle secondary tasks led to less accurate identification of road signs.

In measuring driver distraction, Ward draws a distinction between episodic and continuous driving tasks and their effects—when combined with secondary tasks—on a driver's "workload" and ability to drive safely. Continuous driving tasks, he says, make it easier to see impairments in driving due to secondary tasks. Specifically, hands-free cell-phone conversations demonstrated significant impairment. But in-vehicle tasks consistently showed the most impairment because they combine both cognitive and physical distraction.

Some industry efforts are aimed at locking out cell-phone and ATIS functionality during high workload periods, but until those technological developments are implemented, a driver's discretion is all that limits his or her cell-phone usage. Though he believes legal sanctions against cell phones need enforcement and education, Ward emphasizes that driver education is necessary to understand the risks and to learn when it is safe to engage in secondary tasks.

"Banning cell phones isn't the solution," Ward concludes. Rather, it's determining how to use them appropriately—and safely.

"The drunk driver doing nothing but driving was less impaired than a sober driver using a cell phone or playing with the radio."

Technologies for Modeling, Managing, and Operating Transportation Systems

Evaluation and Improvement of the Stratified Ramp Metering Algorithm through Microscopic Simulation

The Minnesota Department of Transportation (Mn/DOT) has a long history of using ramp metering as a traffic management strategy, though in recent years, some members of the public have questioned the effectiveness of the metering system. Results of a legislatively mandated eight-week ramp meter shutdown study in late 2000 showed that ramp metering is beneficial for increasing freeway volumes, decreasing travel times, increasing speeds, and decreasing crashes. Yet motorists surveyed as part of this study, while agreeing that metering improved traffic conditions, felt strongly that ramp meter wait times were excessive.

These findings prompted Mn/DOT engineers to develop a new ramp control algorithm to better balance freeway flow with ramp wait times. Unlike the ZONE metering algorithm Mn/DOT used prior to the shutdown study, the new Stratified Zone Metering (SZM) algorithm does not depend on historical demand data, but rather, bases ramp metering rates on real-time ramp demand and queue size. Although Mn/DOT began deploying this strategy in 2002 at various locations within the Twin Cities ramp metering system, its effectiveness, especially critical quantitative measures of effectiveness (MOEs) such as system delay and system travel time, had not been substantiated.

That's where researchers from the University of Minnesota's civil engineering department come in. Professor Panos Michalopoulos, along with research fellow John Hourdakakis and research

assistants Baichun Feng and Wu-Ping Xin, are continuing efforts from a recent project in which Mn/DOT's earlier ramp control algorithm was successfully evaluated for two Twin Cities freeways. In this current project, researchers move beyond evaluation to develop a low-cost, innovative method to reliably and quickly evaluate, improve, and optimize the SZM algorithm.

Michalopoulos and his team are focused on two specific objectives: one, identifying how the SZM algorithm compares and contrasts to the ramp metering algorithm used prior to the shutdown study; and two, analyzing the sensitivity of the SZM algorithm to different variables. They integrated a sophisticated control module, which emulates the SZM algorithm, into a state-of-the-art microscopic simulator. They then compared the new stratified metering algorithm with the old algorithm and to a no-ramp-control situation. Through these simulations, detailed statistics have been generated to help the team evaluate critical aspects of the new algorithm's operation including its effect on queue formation, bottleneck operation, and variations of long and short trip travel times. Using a simulator in this way enables testing and study of a variety of ramp control scenarios and allows time to make improvements before a new ramp control strategy is deployed live.

This helps minimize costly and time-consuming field testing and the resultant traffic disruptions.

The results so far suggest that the SZM strategy meets its objective of keeping ramp delays below the predetermined maximum threshold. However, when compared with the ZONE algorithm, the SZM's



emphasis on limiting ramp wait times shifts ramp delays to the freeway mainline and degrades the quality of the freeway flow. Analysis further shows that the SZM strategy is beneficial when compared to the no-ramp-control alternative in terms of improving freeway performance, but during heavy congestion, the SZM is only marginally better than this alternative.

Researchers also have observed that system delay, system travel time, and fuel consumption and pollutant emissions under the SZM control are unpredictable, and that these MOEs may improve or degrade, compared to the no-control alternative, depending on the freeway geometry and demand patterns. This suggests the need to further analyze the trade-offs between freeway efficiency and reduced ramp delay.

Through efforts of this project, these researchers have developed a reliable and efficient methodology for evaluating and improving the SZM algorithm that will greatly assist Mn/DOT in designing, deploying, and operating ramp metering strategies. In future work, researchers will explore additional improvements to the SZM algorithm that factor in ramp queues and other traffic pattern measurements such as the formation of shockwaves. The goal is to “tweak” the SZM algorithm so that it is effective in not only dissipating ramp queues faster while keeping maximum ramp delays well below the desired threshold, but also in smoothing the mainline traffic flow and decreasing the freeway mainline delays.

Identification and Simulation of a Common Freeway Accident Mechanism: Collective Responsibility in Freeway Rear-End Collisions

It’s rush hour and freeway traffic is heavy. The first car in a cluster of seven slows down and a wave of red brake lights spreads as each successive vehicle in the group slows down to avoid hitting the car ahead. But some drivers react faster than others. A few seconds after the first car slows down, the last car in the group collides with the car ahead of it.

It’s a scene that happens every day in high-traffic conditions. Usually, it’s the person who hits the car ahead who receives the blame. Yet studies dating back to the 1950s have suggested that within clusters, or “platoons,” of cars traveling in high traffic, a driver further ahead in the group may actually cause the collision and that such crashes result from the actions of the entire group. Ultimately, if the platoon is long enough, the collision may be inevitable.

Says Gary Davis, associate professor in the Department of Civil Engineering, “I like to think of it as a common bank account. The people with a longer reaction time make a bigger withdrawal from a finite account.” If that account of stopping time is depleted before the last driver in the cluster starts to stop, a collision results.

To further assess this theory, Davis and graduate student Tait Swenson analyzed video recordings of crashes on Interstate 94 in Minneapolis. Their study is part of a larger investigation, “Identification of Accident-Prone Conditions,” funded by the ITS Institute and conducted by Professor Panos Michalopoulos and research fellow John Hourdakakis, both of the Department of Civil Engineering. The goal of this research is to provide low-cost, innovative solutions for identifying causes of crashes in crash-prone freeway locations and to develop a crash avoidance and prevention system.

In a method of study that Davis says is unlike anywhere else in the world, video cameras were installed on high-rise buildings adjacent to I-94. The cameras were connected to a computer that recorded the weekday traffic activity from morning through evening rush hours. Davis and Swenson analyzed three crashes that occurred in locations where it was possible to measure vehicle trajectory information from the video. A computer program allowed them to record the sequence of coordinates representing each vehicle’s trajectory to understand the sequence of events in the crashes. They also analyzed various theoretical examples of what might have happened if each driver’s reaction time or following distance had been different.

The result of the study indicated that of 19 drivers, 10 probably had reaction times that were longer than their following distance.



Gary Davis



The result of the study indicated that of 19 drivers, 10 probably had reaction times that were longer than their following distance. In all three collisions, had the colliding driver maintained a following headway of two seconds, the collision would probably have been prevented. Perhaps more pertinent, they found that for each of the crashes, it was possible to identify actions by earlier drivers in the cluster that contributed to the occurrence of the collision, even though these drivers did not actually collide.

Says Davis, “Short headways translate into higher traffic flows, so one can argue that short headways help make use

of limited freeway capacity.” He suggests that short of having fewer cars on the road or a tremendous improvement in drivers’ competency, deploying collision-avoidance technology in vehicles (or potentially in the road itself) could help reduce traffic delays without, for example, adding more lanes to the freeway.

It’s a situation that Davis compares to air traffic control used in busy airports. “You need some sort of central controller,” he says. “There’s a limit to what you can do with people.”

Computing, Sensing, Communications, and Control Systems

Intersection Decision Support: Improving Safety on Rural Highways

Rural highways are a vital part of our transportation network, but their pastoral setting can hold a hidden danger. Intersection crashes account for more than 30 percent of all vehicle crashes in rural areas; from 1998 through 2000, 62 percent of Minnesota’s intersection-related crash fatalities occurred in rural areas. Far from the city lights, ITS Institute researchers are developing new ways to prevent crashes at vulnerable rural highway intersections, in Minnesota and across the country.

At the center of the research effort is an unremarkable-looking through-stop intersection in southern Minnesota’s Goodhue County, where a divided highway carrying high-speed traffic intersects a two-lane collector road. Led by Intelligent Vehicles Laboratory director Craig Shankwitz, researchers have installed a web of unobtrusive sensors around this intersection, including multiple radar units, laser-based (lidar) vehicle detectors, and visible-light and infrared video cameras mounted on a portable camera mast

overhead. Despite the sophistication of the equipment, most highway drivers pass through without even knowing it’s there.

That unobtrusiveness is a key design goal of the Intersection Decision Support (IDS) project, which aims to produce a system that tracks highway vehicles and uses that data to give drivers stopped on a secondary road better information about approaching traffic, without disrupting highway traffic flow.

“IDS represents a new approach to preventing rural intersection crashes,” says Shankwitz. “Our system focuses on reducing driver error, which is the most common cause of crashes, rather than on restricting vehicle movements.”

Interest in IDS extends beyond Minnesota’s borders, and the Institute has been successful in attracting support for the project through a federal pooled-fund agreement with several other state transportation agencies. Each participating agency will have a portable system temporarily installed at a candidate intersection in its state to evaluate the system’s performance under local conditions

“Our system focuses on reducing driver error, which is the most common cause of crashes, rather than on restricting vehicle movements.”

and to broaden the range of intersection data available for analysis.

After reviewing crash statistics and road geometries of hundreds of intersections, the researchers selected the Goodhue County site to equip with an array of data-gathering sensors. At the study site, the intersection geometry is complicated due to a substantial grade difference between the two halves of the divided expressway. Both the expressway and the rural road are frequently used by large commercial vehicles.

The core of the IDS system is a central processing unit that integrates speed and location data from the system's array of sensors to create a digital snapshot of traffic—including vehicle position, rate, range, and time-to-intersection—10 times every second, both on the main highway and on the collector road. Using predictive algorithms, the processing unit projects vehicle trajectories continuously in real time, and tracks gaps between vehicles on the highway.

The vehicle tracking system has been gathering data around the clock for several months. These data are stored in a spatial database, allowing the research team to search for specific vehicle configurations and turning behaviors. Of particular interest are “near miss” scenarios, in which two or more vehicles cross the intersection within a short time gap; by querying vehicle detector data, it is possible to pull up stored video footage of any such incidents for further human analysis of

driver behavior.

The HumanFIRST Program's VESTR immersive driving simulator also plays a central role in IDS research. Inside VESTR, a realistic model of the research intersection has been programmed, complete with virtual vehicles controlled by data from the real-world intersection. This enables detailed observation of driver response to various intersection conditions in a way that would be impossible on the road. A variety of types of driver interface can also be tested under completely controlled conditions, including critical issues such as information complexity and the varying response patterns of different driver groups, such as older drivers.

Members of the IDS project team have been working with representatives of participating state transportation agencies on the design of the portable data-gathering system. This system will be transported by truck and set up by members of the IDS research team at selected intersections in each state in order to explore possible regional differences in driver intersection behavior.

HumanFIRST researchers have completed initial evaluation of a variety of different interface designs and are currently developing candidate designs for review by participating state agencies. The final design must satisfy a variety of constraints, including effectiveness, maintenance requirements, and compliance with uniform standards for traffic control devices.



The Goodhue County test site. Sensors collect speed and location data, which is used to calculate vehicle position, rate, range, and time-to-intersection on both the main highway and the collector road.



A video monitor in front of test subjects shows the knob as it would appear when installed in a control panel.

Optimal Secondary Controls Using a Configurable Haptic Interface

Can a single knob make a vehicle safer? Professor William Durfee of the Department of Mechanical Engineering thinks the answer is yes. Durfee is conducting research on a new type of control interface that aims to reduce driver distraction by consolidating many non-critical control functions in one multi-purpose knob that behaves differently depending on how it is being used.

Driver distraction due to a complex control interface is becoming more problematic as car manufacturers add new electronic features for in-vehicle communication and navigation. One potential way to reduce the driver's cognitive load is to consolidate secondary controls into a single multi-function device while leaving controls for critical systems on the dashboard.

Durfee's work aims to advance the multi-functional control concept by designing a knob that exhibits different "personalities" depending on the function it is performing. For example, the knob might offer clicking detents when being used to change radio frequencies, but turn smoothly when adjusting temperature. A computerized servomotor system within the dashboard would emulate friction, resistance, and other sensations experienced when using a conventional knob.

In order to determine optimal haptic characteristics for different control functions, Durfee and his collaborators have constructed a unique experimental apparatus. It consists of an unassuming knob connected to a computer-controlled servomotor that emulates a variety of haptic feedback in real time, while a second computer provides auditory feedback, such as the "scratch" of friction or clicks as the knob turns. To create a more realistic testing environment, a video monitor in front of test subjects shows the knob as it would appear when installed in a control panel.

Having knobs with haptic properties that are optimal for the task may reduce errors and make the interface easier to operate.

The testing knob itself is mounted on a specially colored background, which a third computer digitally replaces with a virtual dashboard.

Durfee explains that the function of knobs can be broadly categorized into two types of tasks. The first is to select among a collection of pre-determined settings—for example, the climate control knob in a car. "You can choose to have the air come out on your feet, or the windshield to prevent frost, or all around you for comfort. This would be a selection task where you choose among a set of choices," he says.

The other task is to set a property. With the blower setting in a car, the operator spins the blower knob to get the desired temperature—there are no predetermined settings. Often knobs used for selection have detents while knobs used for setting do not.

Durfee and graduate student Reann Dargus are now embarking on a series of experiments to determine what type of knob works best for each of these tasks, and whether the properties of that "best" knob should be different from person to person.

This becomes particularly important for those operating heavy equipment or who must master complex panels on machines, or for use in buses or airplane cockpits as well as cars, Durfee says. Having knobs with haptic properties that are cued to the task and are optimal for the task may reduce operator error and make the interface easier to operate.

Durfee hopes to use the results from the enclosure simulations to incorporate a servomotor-controlled knob into the dashboard of a STISIM virtual driving simulator, enabling researchers to test the advantages of different feedback characteristics in a driving environment.

Social and Economic Policy Issues Related to ITS Technologies

Sustainable Technologies Applied Research Initiative: Networks and Productivity

Since 2001, a team of researchers from the Hubert H. Humphrey Institute of Public Affairs' State and Local Policy Program (SLPP) and the ITS Institute has been working together to conduct a set of federally sponsored studies, collectively called the Sustainable Technologies Applied Research (STAR) initiative, on how transportation systems can be planned in an increasingly complex social, political, economic, and technological environment. As part of this interdisciplinary team, David Levinson, associate professor in the Department of Civil Engineering, is researching the dynamics of the Twin Cities metropolitan-area freeway network.

Transportation networks such as this are inherently complex systems because of their structural connectivity, dynamic behavior, and nonlinear and heterogeneous interactions between elements. It is this complexity that drives the need for ongoing study of these systems. Levinson's goal in this case is to develop a better understanding of transportation network dynamics over time—that is, how these networks grow and decline. Gaining deeper knowledge in this area is particularly important considering that today's decisions regarding transportation network expansion and contraction significantly alter the choices available to future decision makers.

In previous related research, Levinson, who brings a strong economic component to his analyses of transportation issues, developed a regression and a simulation model, which enabled him to partially examine the impacts of network expansion decisions in one point in time on future choices. He later used network dynamics modeling to bring together relevant transportation models to simulate network growth and further study network properties and dynamics. Now, he is working to expand this network growth model using agent-based modeling techniques, which, more so than trip- and activity-based modeling, provide a powerful, flexible travel forecasting framework

that facilitates the prediction of important macroscopic travel patterns from microscopic “agent” behaviors, and thereby facilitates study on individual travel behaviors.

Levinson's work on this agent-based travel demand model builds on the capability of the pilot model developed in year-four STAR efforts. In the pilot model, travel demands emerge from the interactions of three types of agents: intersections (nodes), arcs (road links), and land use (travelers or trips). But there are other agents in the transportation system, and they have significant impacts on travel demand. It is necessary, for instance, to define agents that represent transit links and railways so that these modes can be studied and more realistic traffic assignment algorithms can be approximated. In his current work, Levinson is using estimated model parameters based on Twin Cities network and land use data to incorporate the emergence of these new agents so that those impacts can be modeled and more fully analyzed.

Because network models play an increasingly important role in urban planning and transportation/land use policy evaluation, Levinson also is working to develop a policy analysis tool that combines the network growth model with policy models that reflect how well a given network satisfies selected performance measures (e.g., congestion levels, accessibility, and system cost). By comparing the predicted networks created using different investment strategies against their performance, the networks with the best performance (or preferred networks) and thus the preferred investment strategies that created them can be selected.

To some observers, decisions to expand transportation networks have been made, by and large, myopically in time and space and have generally ignored non-immediate and non-local effects. While this insular decision-making process tends to improve the relative speeds and capacities of links already in use in a network, the full ramification of network expansion—including future limitations leading to possible worsening conditions on the network—on future infrastructure decisions seldom has been considered.



Student Norah Montes de Oca, David Levinson, and student Mike Corbett

In this study region, five events control the majority of fatalities—the fishing season opener, an auto race, and the Memorial Day, Labor Day, and Fourth of July holidays.

Through ongoing refinements to network modeling techniques, Levinson hopes to provide transportation planners, managers, and other decision makers with the tools they need to better forecast future networks in much the same way similar models are used to forecast population and travel demand.

Sustainable Technologies Applied Research Initiative: Modeling of Wireless Rural Emergency Medical Systems Performance

Although the widespread use of cellular phones is a relatively recent phenomenon, these wireless devices have clearly become an integral part of a new digital lifestyle. And while wireless services afford people on the go the convenience of keeping in touch with family, friends, and work, they also have proven to be an invaluable safety tool for travelers, particularly those driving on rural roads. Over the last decade, use of mobile communications for emergency services has grown exponentially, and the increased demand created by these calls continues to put more and more pressure on the 911 system.

The spread of high-speed and wireless telecommunication throughout rural areas is creating far-reaching social impacts that have prompted University of Minnesota researchers to study ways of enhancing technology's contribution to the development of small communities and the transportation networks that serve them. Specifically, Thomas Horan, research fellow at the Hubert H. Humphrey Institute of Public Affairs, is leading a multiphase examination of wireless networks and their use for emergency management systems. As part of the Humphrey Institute's State and Local Policy Program (SLPP) and the

ITS Institute's Sustainable Technologies Applied Research (STAR) initiative, this study aims to improve the understanding of emergency response and management systems (ERS/EMS) aspects of intelligent transportation systems, giving special attention to measuring and communicating about the performance of these systems.

The research is being conducted in three phases. The first involved developing a draft architecture for investigating rural ERS/EMS based on field visits and an in-depth case study in Minnesota. This framework allowed researchers to identify related technology, institutional, and policy issues and make recommendations for improvements. The second phase, currently underway, involves building on Phase I findings to outline performance metrics and the potential role of technology in monitoring and improving ERS/EMS performance. For example, one use of ITS can be to provide real-time data of system performance, such as ambulance response times. A second case study of the Baxter/Brainerd, Minnesota, area—which included interviews with Minnesota Department of Transportation (Mn/DOT) experts, State Patrol members, and Public Service Answering Points (PSAP) representatives—was conducted to test this Web system.

During this year-long study of the Baxter/Brainerd area, Horan gathered information necessary to gauge the de-

mand for emergency response and the need for technology. Through the process, he discovered that all days are not equal when it comes to fatalities. In this study region, five events control the majority of fatalities—the fishing season opener, an auto race, and the Memorial Day, Labor Day, and Fourth of July holidays. As a result, there can be big spikes in crashes and in response times.



Horan used business-process software populated with data collected from the Brainerd case study to simulate rural EMS systems under both normal and crisis conditions in order to model and assess system performance. The simulation revealed the extent to which rural response systems quickly can become overloaded during peak or crises periods. This simulation was completed by case study interviews that enabled contextual analysis and revealed the need for a more dynamic and comprehensive management information system as well as a forum for sharing EMS performance information across the full range of organizations involved in EMS. The interviews also identified various policy constraints to enhancing EMS systems, such as a lack of funding for new technologies. And, while local EMS providers may have an intuitive understanding of how the entire system performs, evidence shows that there is a lack of systematic data to support, confirm, or refute perceptions about overall performance.

Horan asserts that using technology to respond to emergencies in rural areas should be a top transportation and public health priority. However, experts agree that although the technology exists to support a fully operable, state-of-the-art, end-to-end E-911 emergency management system, the reality of making these networks work efficiently and effectively is complicated. Phase 3 of this STAR task will explore deployment issues for the EMS framework both in Minnesota and nationally. The drive behind all these efforts is to ensure that the speed, accuracy, and efficiency of dealing with 911 calls improve despite the fact that the volume of calls, especially those over wireless systems, continues to increase.

HUMAN PERFORMANCE AND BEHAVIOR

Janet Creaser, Department of Mechanical Engineering Evaluation of Minnesota's NightCAP

Status: Newly funded

Discussions with Minnesota's Office of Traffic Safety indicate a strong need for a rigorous analysis of Minnesota's saturation patrol enforcement strategy to reduce alcohol-related crashes. With 32,100 driving-while-intoxicated (DWI) citations and alcohol-related crashes costing \$350 million in Minnesota last year alone, reducing the number of impaired drivers is a key focus for Minnesota's Comprehensive Highway Safety Plan.

Minnesota conducts saturation patrols under a program called Operation NightCAP (Nighttime Concentrated Alcohol Patrol) as an alternative to sobriety checkpoints, which cannot be conducted legally in Minnesota. These saturations are coordinated by staff in each of the Minnesota State Patrol districts and include participation by county and local law enforcement agencies. Drivers who demonstrate unsafe behaviors (e.g., speeding, running traffic signals) are stopped, giving officers the chance to determine whether alcohol may be a factor in the observed behavior.

Although anecdotal evidence suggests that more DWI offenders are caught through the use of saturations, the actual effectiveness of the campaign in reducing alcohol-related crashes and deterring individuals from driving while intoxicated is unknown. Support for alternative enforcement programs like Operation NightCAP is hindered by a lack of understanding of its influence on the rates of DWIs and alcohol-related crashes. Since its inception, no formal, rigorous analysis of the effectiveness of Operation NightCAP

has been conducted. Moreover, little research has been conducted on saturation patrols in general as an enforcement tool against drunk driving. The objective of this project is to describe the overall impact of saturations on DWI offenses and alcohol-related crashes in Minnesota, as well as identify the operational factors affecting the program's usefulness.

Project URL: www.its.umn.edu/research/database.html

Kathleen Harder, College of Architecture and Landscape Architecture Investigating the Effects of Rumble Strips on the Stopping Performance of Sleep-Deprived Drivers

Status: Completed (in FY05)

For this project, the researchers designed three studies to investigate the influence of in-lane (transverse) rumble strips on the braking patterns of drivers when the rumble strips are used to warn drivers of an upcoming traffic control device. Prior to these studies, no empirical work existed that could provide accurate confirmation of the effects of rumble strips on braking patterns.

The researchers used a simulator to study braking patterns among sleep-deprived drivers who encounter rumble strips upon approaching a stop sign. The 20 subjects were commercial drivers between the ages of 25 and 60 with at least three years' driving experience. Each participant drove the 60-mile test route four times. Driving performance was measured using a battery of tests, including an EyeCheck device, an acuity test, a contrast-sensitivity test, a psycho-motor-vigilance test, and a code-substitution test.

Results show little difference in mean approach speeds to controlled

intersections with or without rumble strips. However, the presence of rumble strips caused drivers to brake to a greater extent earlier in the approach. Although sleep deprivation affected the steering patterns of drivers, it did not seem to affect their braking patterns.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003001

Psychological and Roadway Correlates of Aggressive Driving (Phase II)

Status: In progress

A greater understanding of the factors that contribute to aggressive driving will allow for the development of programs and policies to prevent and reduce it. This study was conducted to better understand the psychological and roadway correlates of aggressive driving.

The study had two phases. In phase one, survey data were used to investigate the relationship between personality, emotional and behavioral variables, and self-reported driving behavior. In phase two, the findings were validated in a driving simulator experiment. The data yielded a number of interesting findings; in particular, there were significant differences in driving behavior between drivers characterized as "high hostiles" and those characterized as "low hostiles." The researchers' focus on psychological traits, emotional states, and behavioral tendencies is proving to be a valuable way to understand aggressive driving behavior; their goal is to begin the process to determine strategies for mitigating it.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002034

Low-Cost Innovative Approaches

to Improve Safety at Unsignalized Intersections on Four-Lane Highways

Status: Newly funded

There is national interest in using low-cost innovative treatments to improve safety on highways in the United States. Intersection crashes represent a significant portion of total crashes nationwide; they account for an average of 9,000 fatalities and 1.5 million injuries annually. Without resorting to roundabouts or grade separations, there are a number of relatively low-cost approaches that are either already in use in other countries or that could be developed to improve the safety of unsignalized intersections on four-lane divided highways.

In an iterative design process, the researchers aim to develop innovative and viable safety improvements and use computer simulation to help select viable safety treatments. It is likely that, if implemented, the recommended improvements would have a significant impact on reducing the number and severity of crashes at unsignalized intersections on four-lane divided highways. Consequently, the research results should greatly benefit motorists in Minnesota and across the United States.

Project URL: www.its.umn.edu/research/database.html



Tom Smith, School of Kinesiology
Reducing Risk-Taking at Passive

Railroad Crossings with Active Warnings

Status: Completed (in FY05)

This simulated driving study evaluated driver interaction with a low-cost active warning system being considered by Mn/DOT for potential installation at passive highway-rail intersections (HRI). The objective of the study was to ascertain if, relative to HRIs with passive signage, drivers interact more cautiously with HRIs equipped with active warning system technology.

The study was conducted using a simulated driving environment consisting of various HRI scenarios and 25 subjects.

Major results show that the presence or absence of a train, fog, or signage significantly affects dependent variables for all measurement intervals; the incidents of vehicles beating a train or hitting a train are higher with passive advance warning signs, relative to active warning signs; with a train present and clear visibility, for all measurement intervals, active advance warning signs are associated with lower mean vehicle speeds, compared to mean speeds observed with passive advance warning signs; active advance and crossing warning signs were perceived by respondents as more usable and more perspicuous than passive advance and crossing warning signs; and finally, flashing words (e.g., a variable message sign) are perceived by respondents as more perspicuous than flashing lights on an active advance HRI warning sign.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2000041

Active Advance Warnings at Highway-Rail Intersections

Status: Newly funded

Although active advance warnings (AAWs) are not currently permitted at highway-rail intersections (HRLs), a recently completed Mn/DOT-sponsored simulated driving study by the principal investigator documents the potential safety benefits of installing AAWs at HRLs. Unlike AAWs at roadway signalized intersections, there are no dilemma zones associated with AAWs at HRLs, because at-crossing active warnings at HRLs do not have a (yellow) caution mode. Further, the AAW configurations evaluated in the previous study were limited. Nevertheless, if installation of low-cost active warning technology at currently passive HRLs proves feasible, including AAWs at HRLs is likely to receive serious consideration.

To further understanding among Mn/DOT and the surface transportation community regarding the impact of HRL AAWs on driver behavior, this research will conduct a simulated driving study to examine driver interaction with different types and configurations of HRL AAWs under both clear and limited-visibility driving conditions. The rationale is that, relative to AAWs at signalized intersections, understanding driver effects of HRL AAWs is more limited, and careful documentation of which type of HRL AAW system design might best promote safe driver behavior at HRLs has not yet been collected.

Project URL: www.its.umn.edu/research/database.html



Mike Wade, School of Kinesiology
Accident Analysis for Low-Volume Roads

Status: Completed (in FY05)

For this project, three sets of analysis were carried out on the database. First was a descriptive analysis of the data to determine the general frequency rates of accidents. A second identified dangerous roadways. Counting the number of crashes on specific roadways and dividing this number by the average daily travel (ADT) on a roadway generated crash rates for those roadways, including county state aid highways (CSAHs), county highways, and township roads. Roadways with the highest 5 percent were considered significantly dangerous. In the third analysis, crash rates were generated for specific locations. This method identified 14 dangerous locations: 9 on CSAHs, 3 on county highways, and 2 on township roads. There were only 235 cases where no improper driving was implicated. The remaining 1,554 cases suggested that driver error was the major cause. The factor most likely to be involved in an accident on a highway with an ADT of less than 400 is an animal. Road design factors such as number of lanes and the speed limit seem to be the factors related to these accidents.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002008

Deer Avoidance Research: Use

of Motion Detector Flashing Light

Status: Completed (in FY05)

This study explored three signage techniques in an attempt to reduce the incidence of vehicle/deer collisions on highways in Minnesota. A simulated environment was created along a stretch of U.S. Highway 23 near Marshall, Minnesota, with participants chosen from the University of Minnesota and the surrounding community. The simulation consisted of a standard warning sign as well as a prototype of the experimental signage. The prototype consisted of a beacon light attached to the top of the warning sign designed to flash when deer were present. During the simulation, participants were exposed to the standard signage as well as the new signage with and without the beacon flashing. The main objective was to determine whether the prototype signs would modify driver behavior such that drivers decreased their speed. The study found that the prototype signage was effective in decreasing the speed of the participants when the beacon light was flashing. These results were consistent across the variations of age and gender. The results for the prototype signage with the beacon light turned off were essentially no different from the standard signage.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002023



Nic Ward, Department of Mechanical Engineering
Rural and Urban Safety Cultures

Status: In progress

Motor vehicle crashes are a predominant cause of mortality in rural areas. Persons involved in a rural crash are three times more likely to die than persons involved in an urban crash. Since most rural crashes involve rural drivers, it is necessary to consider the pertinent human factors by examining the relationship between the personalities and attitudes of rural drivers toward safety and the higher rural crash rate and driving style relative to the urban context. This project attempts to support the development of a human-centered intervention to reduce the loss of life resulting from the high rural crash rate in Minnesota by investigating psychological and social factors that may predispose rural drivers to drive less safely.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005058

Driving Performance During 511 Information Retrieval and Cell Phone Conversation Tasks

Status: Newly funded

Currently, Minnesota has a 511 service that users may access while driving. There is considerable debate about cell phones as a risk

factor in traffic crashes. Mn/DOT research funded in 2003 will assess the "relative" risk of cell phone use compared to other common risk factors, including existing in-vehicle tasks and alcohol. As a logical and necessary extension of that research, this research will assess cell phone use for 511 applications compared to conversational cell phone interactions.

Project URL: www.its.umn.edu/research/database.html

Albert Yonas, Institute of Child Development
Chromatic Perception Effects on Collisions with Snowplows

Status: In progress

Low-luminance contrast conditions, such as those created by blowing snow or fog, constitute some of the most hazardous conditions that drivers commonly experience. Recent experiments indicate that under fog-like conditions, people perceive themselves to be traveling significantly slower than they actually are. To compensate, they speed up. This low-luminance perceived slowing is comparable to the perceived slowing that occurs at equiluminance (no-luminance contrast), where motion information is carried by chromatic contrasts alone.

To measure the effects of low-luminance contrast and other factors on drivers' ability to perceive that they are approaching a vehicle ahead, a laboratory-based computer-simulated experimental setup was devised. In these studies, data were collected from each participant to establish the minimum velocity threshold for discriminating approach from withdrawal. The computer display presented a square similar in retinal size to that of a vehicle ahead on a highway. The display translates in a random direction, and at the same

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time it either expands (specifying approach) or contracts (specifying withdrawal). An adaptive program regulates the velocity to find the value at which participants were correct on 75 percent of the trials. Using these methods, the researchers found that as contrast between the simulated vehicle and background is reduced, much higher velocities are necessary for approach to be detected. In addition, a low-contrast display that flashes on and off, rather than being presented continuously, reduces sensitivity to information for a potential collision.

Physical measurements of luminance and color-contrast under real fog and blowing snow conditions were made. Researchers measured the way that snow filters the frequencies of light reflected from a snowplow and its surroundings in order to begin evaluating the effects of the paint colors selected on the availability of luminance-contrast and color-contrast information.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003037

Improving the Ability of Drivers to Avoid Collision with Snowplows in Fog and Snow

Status: In progress

The researchers have created a laboratory test bed for investigating the effects of blowing snow, fog (luminance contrast), flashing warning lights, and color on the ability of drivers to perceive that they are approaching or withdrawing from a simulated vehicle. Findings indicate that lowering the luminance contrast between the image of a vehicle and the background has a powerful negative effect on the ability to perceive approach. In a low-contrast situation, drivers required twice as much retinal motion as normal to begin to sense

approach. Flashing lights, such as those mounted on snowplows to attract attention, also interfere with motion perception.

The researchers have continued work to characterize the chromatic contrast effect of blowing snow and fog on the color space by making systematic physical measurements on a selected number of carefully chosen color surfaces. In addition, they have begun to use their computer-controlled laboratory simulation, and well-understood psychophysical methods, to investigate the impact of vehicle color and lighting enhancements. For example, they are investigating the effects of the number, location, color and flashing of warning lights on the ability to perceive that a driver is approaching a vehicle. Results at this time suggest that flashing displays may impair the ability of drivers to perceive that they are approaching a snowplow that is ahead.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005

Mohamed-Slim Alouini, Department of Electrical and Computer Engineering

Bandwidth and Power-Efficient Modulations for Multimedia Transmission over Wireless Links

Status: In progress

This project is motivated by the demand of spectrally and power-efficient transmission systems of multimedia traffic data (not only voice but also image and video) over wireless links. The main objective is to design and evaluate the performance of hierarchical constellation systems that offer different degrees of error protection and/or different rates for various bit streams.

The main research achievements include the development and performance analysis of a variable rate non-coherent M-FSK modulation scheme for power-limited systems, the derivation of the exact-bit error rate expressions for a variety of hierarchical PSK and QAM constellations, and the investigation of the effect of fading as well as timing and phase-synchronization errors. This project is also pursuing several applications of hierarchical constellations, in particular, for simultaneous voice and data transmission over fading channels; for multi-resolution data transmission; and for multi-user opportunistic scheduling.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003017

Vladimir Cherkassky, Department of Electrical and Computer Engineering

Quality of Service Implementation for Transmission of Video Data (Phase II)

Status: Completed (in FY05)

As the need to monitor traffic conditions on highway systems

increases, the ability to get a clear video picture decreases due to network congestion. There are many Quality of Service (QoS) implementations available on the market for high-traffic networks, but none implement dynamic priority assignment changes to different network traffic. This is very useful for highway video surveillance using camera systems attached to a limited bandwidth network. This project used freely available software and low-cost hardware to provide such a system. A working prototype of the system has been developed and a detailed performance analysis was performed.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003010



Max Donath and Craig Shankwitz, Department of Mechanical Engineering

Toward a Multi-State Consensus on Rural Intersection Decision Support

Status: In progress

Minnesota has partnered with California and Virginia in a pooled-fund consortium, the Intersection Decision Support (IDS) project, to improve safety at intersections. Improved safety will be characterized by a reduction in both the frequency and the severity of crashes. The consortium is looking at both near-term and far-terms solutions that are effective, deployable, affordable, and beneficial not only to the participating

states, but to the nation as a whole.

The focus of the Minnesota effort is rural intersection safety. Crashes at rural intersections, although less frequent than those at urban or suburban intersections, are oftentimes more catastrophic than their counterparts because of the high vehicle speeds associated with them. The National Safety Council estimates that 32 percent of all rural crashes occur at intersections. Moreover, approximately one in every four fatal crashes occurs at or near an intersection. Because of the high speeds (and the associated high levels of kinetic energy), the ratio of intersection crash fatalities to intersection crash frequency is higher for rural intersections than for urban or suburban intersections.

To create a system that can be deployed nationwide, the extent of the national problem must be understood (and quantified where possible), and a nationally applicable solution to that problem must be designed, developed, tested, and evaluated. The University of Minnesota and the Minnesota Department of Transportation have initiated a State Pooled-Fund study to gain a national basis for deployment of the IDS project. The plan consists of three facets. The first is a review of state intersection crashes for each participating state. Crash data will be used for two purposes: to understand rural intersection crashes on a national basis, and to identify candidate intersection(s) for subsequent instrumentation and study.

The second facet is to participate in the process to design and refine candidate intersection driver-infrastructure interfaces. Representatives from these pooled-fund states will participate in driver interface workshops and provide

input into the effectiveness of the design and its feasibility from the deployment, operations, and maintenance viewpoints.

The third facet is the development of a portable intersection surveillance system that can be used to instrument candidate intersections as a means to acquire data regarding the behavior of drivers at rural intersections over a wide geographical base. Collection and analysis of such data will indicate whether regional differences exist regarding how drivers accept gaps at rural intersections, and whether these differences are likely to affect the operation of the IDS system.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004039

Ravi Janardan, Department of Computer Science and Engineering
Real-Time Collision Warning and Avoidance at Intersections
Status: Completed (in FY05)

Monitoring traffic intersections in real time as well as predicting possible collisions is an important first step toward building an early collision-warning system. In this project, the researchers present the computer vision methods used in a system addressing this problem and describe the practical adaptations necessary to achieve real-time performance. In their results, they present a novel method for three-dimensional vehicle size estimation and describe a method for target localization in real-world coordinates, which allows for sequential incorporation of measurements from multiple cameras into a single target's state vector. Additionally, they developed a fast implementation of a false-positive reduction method for the foreground pixel masks and a low-overhead collision-prediction

algorithm using the time-as-axis paradigm. The proposed system was able to perform in real time on videos of quarter-VGA resolution. The errors in target position and dimension estimates in a test video sequence are quantified.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002025

Taek Mu Kwon, Department of Electrical and Computer Engineering (Duluth)

An Automatic Visibility Measurement System Based on Video Cameras (Phase II)

Status: Completed (in FY05)

Poor-visibility conditions often lead to large-scale chain crashes that might have been prevented had motorists been warned to reduce speed and remain cautious before moving into the poor-visibility zone. The objective of this research was to advance visibility measurement technologies that compute visibility by processing images captured with video cameras.

There are two fundamental difficulties in measuring visibility. The first is that visibility is a complex multivariable function of many parameters such as objects available, light sources, light scatter, light absorption, etc., so that measurements of one or two parameters (as in most of today's visibility meters) cannot accurately estimate the true human-perceived visibility. On the other hand, any attempt to measure every possible atmospheric parameter to derive human-perceived visibility is simply too complex and costly. The second source of difficulty is attributed to the attempt to express the spatially variant nature of atmospheric visibility using a single representative value, distance. It works only if the

atmosphere is uniform, which rarely happens

A solution developed by the researchers is to measure visibility using visual properties of video images (perceived information) instead of indirectly measuring physical properties of atmosphere and converting them to visibility. The spatial variance problem in visibility was solved by introducing a new concept of relative measurement of visual information referred to as the relative visibility (RV). The researchers also studied the limitation of charge-coupled device cameras in visibility measurement applications and show how to overcome them through spatially arranged multiple targets. In addition, they explored various apparatuses of near infrared (NIR) light source and cameras for measuring night visibility.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2000024



TMC Traffic Data Automation for Mn/DOT's Traffic Monitoring Program

Status: Completed (in FY05)

The Minnesota Department of Transportation (Mn/DOT) has been responsible for collecting, analyzing, and publishing traffic counts from the various roadway systems throughout the state. The traffic reporting system—mainly developed by the Traffic Forecasting and Analysis Section (TFAS) of Mn/DOT—has been used in several federal programs, internal Mn/DOT applications, and by the private sector. This project sought to continue TFAS automation efforts by automating the TMC portion of traffic data (ITS-generated data) contributed to Mn/DOT's Traffic Monitoring System.

The focus was to develop an Internet-based system that produces computerized reports on continuous and short-duration count data. One of the challenges was in dealing with missing and incorrect data produced by faulty conditions of traffic data collection systems, including detectors and communication links. This study found that data imputation techniques based on spatial and temporal inferences of traffic flow can overcome the difficulties and produce accurate statistical data. One unresolved issue in this project was dealing with the stations in which nearly no data are available for the entire year, which was observed from two to three percent of the short-duration count stations. This problem is left for future work.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2001033

Integration of RTMS and SQL to Mn/DOT Next Generation R/WIS (Phase II)

Status: In progress

In the past, Road/Weather Information Systems (R/WIS) data and traffic data have mostly been managed in isolation, and thus the benefits attainable by correlating both types of data have not been realized. The researchers believe that correlating historical and real-time traffic data with R/WIS data can lead to better information. The objective of this project is to bridge the gap between R/WIS and traffic data by developing a new data collection and SQL database model that provides seamless integration. The goals for the developed model include reliable data collection, efficient data mining, and uniform data access for integrated R/WIS and traffic data applications.

For the choice of traffic sensors, a radar-based non-intrusive method called Remote Traffic Monitoring Sensor (RTMS) was originally proposed based on the advantage that it does not require lane closures or cutting into the roadways. However, this new project will add the available loop detector data located near R/WIS sites to the RTMS data in order to increase the number of integrated base stations. This addition will complement the limited number of the present RTMS installations (two) and expand the data flow from more diverse types of data sources. The loop detector data will be collected from the Transportation Data Research Laboratory data archive through online automation and loaded into the project's data model.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005046

Section Travel-Time Measure-

ment and Vehicle Classification Using Inductance Signatures of Loop Detectors

Status: In progress

In Twin Cities' metro-area freeways, loop detector stations have been installed at a half-mile spacing, forming sections. Each section thus consists of two sets of detector stations: one at the section entrance (upstream) and the other at the section exit (downstream). This research is studying a new way of measuring the average section travel time by tracing inductance signatures of vehicles from a pair of locations, the section entrance and exit. The basic methodology applied in this research is a blind de-convolution of inductance signatures that are directly obtained from loop detectors. From a system point of view, loop detector outputs can be considered as a result of convolution between the true vehicle inductance signature and the loop detector system function. Blind de-convolution is an attempt to restore the features of the original inductance waveform by reversing the loop convolution process. Time-stamped features of the upstream station and re-identification of those features at the downstream station enable the computation of travel time. As a preliminary study of hardware implementation, the researchers developed a "hardware-in-loop" system that interfaces a Canoga card with actual loops.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003027



Development of Portable Eight-Channel WIM Analysis System Based on Analog WIM Signals

Status: Newly funded

Weigh-in-Motion (WIM) data have been key to the design of pavement structures. Recently, Mn/DOT has begun to expand WIM equipment installations using quartz Lineas technologies to extend the present WIM bases to major roadways in the state. However, systems available from WIM vendors lack any capability of analyzing the raw WIM analog signals. Therefore, it has been difficult to determine how much the sensor readings are trustworthy, since the only available outputs from the existing systems are the final converted weight and axle data.

This research seeks to develop an eight-channel portable WIM analysis system that can simultaneously probe and analyze eight analog channels and thus be used as a system diagnostic tool. This new system will be designed as an advanced version of the two-channel system developed earlier in 2003 by the present researcher. The new system will have two operational modes: a probe mode and a data-collection mode. In the probe mode, it will simultaneously probe eight WIM channels, analyze the raw analog signals, and report the analysis results. The test report will include faulty channel conditions, signal health state, noise level, and signal deviations from the normal level from which data quality can be

assessed or respective maintenance can be activated. In the data-collection mode, the system will have a real-time weight translation and recording capability so that it can serve as a portable WIM data acquisition system for up to eight channels (four lanes). Such a function not only helps explore development of portable WIM sensors but also provides a temporary replacement for malfunctioning WIM equipment units.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006022

Nikolaos Papanikolopoulos, Department of Computer Science and Engineering

Finding What the Driver Does

Status: Completed (in FY05)

Most research depends on detecting driver alertness by monitoring a driver's eyes, face, head, or facial expression. This research presents methods for recognizing and summarizing driver activities by using the appearance of the driver's position, and changes in position, as fundamental cues, based on the assumption that periods of safe driving are periods of limited motion in the driver's body. The system uses a side-mounted camera and uses silhouettes obtained from skin-color segmentation for detecting activities. The unsupervised method uses agglomerative clustering to represent driver activity throughout a sequence, while the supervised learning method uses a Bayesian eigen image classifier to distinguish between activities. The results validate the advantages of using driver appearance obtained from skin color segmentation for classification and clustering purposes. Advantages include increased robustness to illumination variations and elimination of the need for tracking and pose

determination.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004059

Recognition of Human Activity in Metro Transit Spaces

Status: Completed (in FY05)

This research introduces a vision-based system to monitor for suspicious human activities at a bus stop. The system currently examines behavior for drug dealing activity, which is characterized by individuals loitering at a bus stop. To accomplish this goal, the system must measure how long individuals loiter at or near the bus stop. To facilitate this, the system tracks individuals from the video feed, identifies them, and records how long they spend at the bus stop.

The system is broken into three distinct portions: background subtraction, object tracking, and human recognition. The background subtraction and object tracking modules use off-the-shelf algorithms and are shown to work well following people as they walk around a bus stop. The human recognition module segments the image of an individual into three portions corresponding to the head, torso, and legs. Using the median color of each of these regions, two people can be quickly compared to see if they are the same person.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003030



Deployment of a Tracking-Based Monitoring and Data-Collection System

Status: In progress

This project is working toward the development and deployment of a flexible, portable, and reliable intersection-monitoring and data-collection system, based on vehicle-tracking methodologies implemented on one or more video cameras. Research activities include computation of a variety of traffic and behavior data such as turning-vehicle counts, vehicle trajectories, vehicle classes, delays, lane changes, gap acceptance behavior by turning vehicles, speed variations, safety-related data, and other types of intersection data as needed by traffic engineers. The proposed system could be used for assessing the effectiveness of existing signal timing plans and operational methods and the level of intersection safety. The researchers' approach includes developing a user-friendly interface and employing existing camera hardware. The researchers also envision using the proposed system as the main tool for before/after study of the effectiveness of intersection and local-area improvement treatments.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003042

Freeway Network Traffic Detection and Monitoring Incidents

Status: Newly funded

Freeway management requires advanced data-collection methods. In particular, special emphasis is given to data such as vehicle trajectories, gaps, lane changes, and accelerations in areas like weaving sections, freeway bridges, tunnels, and freeway segments around airports and rail and bus stations. Vehicular—and even pedestrian—traffic is present in most of the sites. Collecting traffic data and recognizing patterns or events of interest is a complex process, since it often involves crowded scenes. This project is investigating the use of cameras in the visible range in order to collect data such as vehicle trajectories in the freeway system and classify certain events as ones that merit further examination by the operator. One example is a car stalled/stopped on a bridge or a car driving erratically. Right now, several states or federal agencies use humans to observe these events and collect data. This research will explore the development of an automated system to collect traffic data and notify human operators about interesting data or events in the general vicinity of the freeway network.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005070

Multi-Camera Monitoring of Human Activities at Critical Transportation Infrastructure Sites

Status: Newly funded

This research will investigate the use of multiple cameras for monitoring human activities at critical transportation infrastructure sites. This work leverages work performed under the researchers'

recent Department of Homeland Security contract. In particular, novel methods for employing image-based rendering to extend the range of applicability of human-motion recognition systems in transportation settings will be developed. The researchers also plan to demonstrate the use of image-based rendering to generate additional training sets for view-dependent human-motion recognition systems with direct applicability to critical transportation sites. Input views that are orthogonal to the direction of motion will be created automatically to construct the proper view from a combination of non-orthogonal views taken from several cameras.

To extend the capabilities of motion-recognition systems, image-based rendering will be utilized. The proposed methods will further be developed to automatically detect and spatially estimate an occlusion (common in crowded outdoor scenes) in world coordinates. The algorithms will be tested at a Mn/DOT-selected site (bridge, airport, or tunnel) or alternatively at two transit stations, one located in the Uptown (Minneapolis) area and the other at the Mall of America. The proposed methods are directly applicable to a wide variety of transportation infrastructure sites.

Project URL: www.its.umn.edu/research/workplan/P2006009.html



Portable Traffic Video Data Pro-

cessor

Status: Newly funded

The ultimate goal of this project is to produce a traffic vision data processor—in other words, a PC-based system that will accept videotapes from intersections, weaving sections, etc., and produce a certain set of desirable traffic data or other interesting traffic events. Depending on the traffic domain, interesting events might range from being clear cut and easily pre-specified by the user to being more abstract and defined as those events that deviate from normal behavior by some user-specified threshold. In general, for uncontrolled environments such as traffic sites where the target behaviors vary depending on the type, location of intersection, camera-viewpoint, etc., it makes more sense for the system to learn normal target behavior patterns from previously observed target trajectories for ease of portability.

Extracting target trajectories from image sequences in unconstrained environments such as outdoors is hard due to the dynamic nature of the scene that affects accurate target registration. Without a good estimate of target trajectories, it is impossible to derive any usable information about the target's behavior in a scene. Hence, the main challenge in an application such as vision-based control is achieving robust target tracking.

Although several vision-based trackers with emphasis on outdoor scenes exist, most trackers make use of a single visual cue that can provide good target detection as long as certain constraints are satisfied. As soon as the scene changes in ways that violate the assumptions, the cues fail to provide any useful information, thereby rendering the

tracker inaccurate in its objective. Hence, the researchers propose to make use of multiple visual cues so that the range of successful operation of the tracker can be increased by reducing the scene constraints. Finally, the proposed system will include mosaicking tools.

Project URL: www.its.umn.edu/research/workplan/P2006055.html

Rajesh Rajamani and Lee

Alexander, Department of Mechanical Engineering

Automated Winter Road Maintenance Using Road Surface Condition Measurements

Status: In progress

This project aims to develop an automated sander control system for a snowplow using the friction coefficient of the road surface and pavement temperature as key measurements for feedback.

The project consists of two major technical activities: 1) Improvement of an existing tire-road friction measurement system on the SAFEFLOW by using additional piezo sensors mounted on the insides of the tires of the snowplow. These additional sensors will help improve the accuracy and reliability of the friction measurement system. 2) Automation of the snowplow sander using real-time measurements from the friction measurement system and a pavement temperature measurement sensor, and experimental evaluation of the performance of the automated system on the SAFEFLOW. This project will lead to the development of valuable winter maintenance technology in which knowledge of pavement conditions is used to keep roads in safe condition. The technology will help reduce material costs, help better utilize maintenance crews, and lead to safer roads in

winter.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005037



Lateral Stability of a Narrow Commuter Vehicle

Status: In progress

A relatively unexplored but very promising solution to the problem of traffic congestion is the adoption of narrow vehicles for commuter travel. Narrow vehicles like motorcycles can significantly increase highway capacity by the use of half-width lanes. However, for the general public to adopt this form of personal transportation, narrow vehicles should perceptibly provide the same ease of use and the same level of safety as passenger sedans.

The research team has developed a new concept vehicle that is relatively tall compared to its track width so as to provide a travel height that is comparable to that of other vehicles on the highway. To help the driver balance a relatively tall, narrow vehicle, it incorporates an electronic tilt control system that ensures tilt stability. The tilt control system balances the vehicle and improves ease of use, especially on curves where the vehicle must lean into the curve to ensure tilt stability.

For this project, the design and implementation of a control system that ensures the tilt stability of the prototype narrow vehicle is presented. The control system—

called Steering Tilt Control (STC)—uses steer-by-wire operation in which the front wheel steering angle controls tilt while perceptibly allowing the driver to use the steering angle for lateral control. A novel innovative algorithm was developed for STC that satisfies both the driver handling and tilt stability requirements.

The project includes significant detail on the design of the prototype narrow vehicle constructed by the research team, including dynamic modeling for narrow tilting vehicles. It also includes experimental results on the performance of the control system. The simulated system and the experimental vehicle are compared to illustrate the simulation limitations and also show similarities that validate the model. Experimental results show that the vehicle is stabilized very well by the controller within the limitations of its prototype hardware.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2001030



Rajesh Rajamani, Department of Mechanical Engineering
GPS-Based Real-Time Identification of Tire-Road Friction

Coefficient

Status: Completed (in FY05)

This project concentrated on the development of real-time tire-road friction-coefficient-estimation systems for snowplows that can reliably estimate different road surface friction levels and quickly detect abrupt changes in friction coefficient. Two types of systems were developed: a vehicle-based system and a wheel-based system. The vehicle-based friction measurement system uses vehicle motion measurements from differential GPS and other on-board vehicle sensors. The wheel-based friction measurement system utilizes a redundant wheel that is mounted at a small angle to the longitudinal axis of the vehicle. In addition to winter maintenance applications, real-time identification of the friction coefficient is expected to be valuable to other vehicle systems, including ABS, skid-control, collision avoidance, and adaptive cruise control systems.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002026

Craig Shankwitz, Department of Mechanical Engineering
Bus Rapid Transit Technologies: Assisting Drivers Operating Buses on Road Shoulders

Status: Completed (in FY05)

The Federal Transit Administration (FTA) has identified bus rapid transit (BRT) as a means to increase the efficiency of transit operations while maintaining transit's proven safety record. Because of the limited right-of-way available to build new (and possibly dedicated) lanes for BRT operations, the FTA has identified lane assist as an emerging technology that will enable deployment of BRT systems. The premise behind lane-assist technology is to increase the safety of

BRT vehicles as they operate in the more unique environments, such as narrow lanes. Lane-assist technology will allow BRT vehicles to operate at the desired higher operating speeds while maintaining the safety of the passengers, BRT vehicle, and motoring public.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2001046

Advanced BRT: Innovative Technologies for Dedicated Roadways

Status: In progress

In the United States, a number of transit agencies are either operating bus rapid transit (BRT) systems or are in the process of initiating this service. For example, Twin Cities Metro Transit operates a BRT system using a network of 200 miles of road shoulders to allow bus passage during periods of high traffic congestion. Lane Transit in Eugene, Oregon, and the Cleveland Regional Transit Authority are considering a BRT system, both of which are likely to use lane-assist technology on dedicated, narrow lanes.

The present Intelligent Vehicles (IV) Lab lane-assist system is based on precise vehicle positioning technology and a high-accuracy digital road "map." This system requires a reasonably clear view of the sky overhead in order to receive GPS satellite information. Without a clear view of the sky, GPS information is unavailable, disabling the lane-assist system. Urban canyons, roads with tall trees located close to the roadway, bridges, and underpasses all represent areas where the IV Lab system cannot receive satellite signals, and therefore cannot operate.

This research will explore augmenting the IV Lab lane-assist

system with ranging and positioning technology that will allow the system to operate in the difficult environmental conditions described above. Alternative ranging and positioning sensors will be analyzed, modeled, and eventually incorporated into the IV Lab lane-assist system. Successful augmentation will result in a system that meets the operational and robustness needs of transit agencies as well as the cost-effectiveness and reliability needs of the bus manufacturer and its original equipment manufacturer (OEM) supplier.

Technologies to help the driver deal with traffic adjacent to or crossing over the dedicated bus lanes are also addressed as a first step to move BRT operations from dedicated to mixed traffic environments.

The IV Lab intends to work with transit agencies and bus manufacturer(s) to deploy an augmented DGPS-digital map lane-assist system for BRT narrow-lane applications in the United States.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002041



Driver-Assistive Systems for Rural Applications: A Path to Deployment

Status: In progress

The first component of this project is to develop and implement an automated means to collect geospatial data and process it in order to create a geospatial database suitable for use in driver-

assistive systems. Researchers will equip a vehicle with DGPS, sensing systems, image-capture hardware, image-processing software, and data-acquisition equipment that will facilitate the real-time determination of the global position of a paint stripe as a vehicle travels on a lane. With this sensory and data-acquisition system, the location of all paint markings on the roadway can be accurately determined and used as the basis of a multipurpose high-accuracy geospatial database.

A complement to the image-processing task will be the use of paint striping machines to collect geospatial data. The image-based system will be modified so that the global location of the paint nozzle can be determined from a sensor suite and a DGPS receiver located on the paint striping machine. Sensors will be used to determine when the paint is applied, and raw data from these systems will be converted into geospatial information.

The second component of this project is to form partnerships with county engineers who are responsible for snow removal in difficult environmental and visibility conditions. Two Minnesota counties (Polk and St. Louis) agreed to work with the Intelligent Vehicles Lab to test these systems. Initially, the goal was to map 22 miles of road in each county and train drivers to operate the system on these roads prior to the commencement of plowing operations. The Polk County system was based on a DGPS system that employs GPS corrections provided by a geosynchronous communications satellite. Such systems obviate the need for a local, ground-based GPS base station and the wireless communication equipment needed to get the correction to the roving

vehicle, thereby offering sufficient performance at a much lower cost. However, satellite-based correction systems are slower to recover if satellite information or corrections are lost. Testing in Polk County will provide the opportunity to explore the tradeoffs between conventional and satellite-based correction systems. The GPS component of the St. Louis County system was based on a conventional RTK system.

During the winter of 2003–2004, operators in St. Louis County determined that they didn't require a vision-enhancement system, due to the presence of dense conifer forests adjacent to the roads that block blowing snow and provide a solid visual reference. However, Polk County, which is flat, has few trees, and suffers from significant white-out events, was very pleased with its driver-assistive system and requested St. Louis County's when they found out it was available. A second plow in Polk County was equipped with the technology, and an additional 150 miles of roads were mapped. Its system has been operational since October 2004 and has been used regularly throughout the winter of 2004–2005.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002009

Gang Plowing Using DGPS

Status: In progress

Gang plowing is one method used by Mn/DOT to increase the productivity of snowplow operations. However, these gains in productivity often come at the expense of increased driver stress. These higher stress levels are the result of the low visibility caused by the snow clouds created by the lead snowplow and by anxious drivers trying to pass between the slower-moving plows.

This research aims to improve gang plowing through the use of a driver-assistive system combining tactile steering feedback with throttle and brake actuators to help the driver of the following vehicle maintain the proper distance and lane position behind the lead vehicle.

The driver-assistive package improves safety on two fronts. First, driver stress and therefore driver fatigue will be reduced; alert drivers are in better control of their vehicles. Second, the driver-assistive system allows a tighter formation for the plows, reducing the opportunity for a rogue motorist to try to squeeze in between the ganged snowplows. A side-scanning laser sensor and a "virtual mirror" are also used to detect the rogue motorist trying to violate the gang formation.

This research builds on the driver-assistive work done under the Specialty Vehicle Initiative pooled-fund project. The results of the work performed under this project will be demonstrated on an actual road, Minnesota Trunk Highway 101 between Rogers and Elk River.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002038

Infrared Sensors for Driver-Assistive Systems for Specialty Vehicles, Including Snowplows

Status: In progress

This research is investigating the applicability of infrared imaging sensors for use as a driver-assistive display interface for general specialty vehicle operations and as a sensor integrated into the University of Minnesota Intelligent Vehicles Lab's driver-assistive system. This system, which includes radar-based obstacle detection, has been proven in several tests: in snowplows on Trunk Highway 101 between Elk River and Rogers, Minn.; in snowplows in field tests at the Rosemount Research Station; and on a fleet of vehicles including a Minnesota State Patrol car operating on T.H. 7 between Hutchinson, Minn., and I-494 in the Twin Cities.

Automotive radar suffers two fundamental shortcomings. The first is its inability to detect and "follow" obstacles moving perpendicular to the vehicle direction of travel. In contrast, the human visual processor driven by an imaging sensor (i.e., infrared sensors) is very sensitive to cross-track motion. The second shortcoming is that automotive radar will provide information pertaining to where an obstacle is (range, range rate, and azimuth angles) but not information regarding what the obstacle is. Infrared sensors can provide information regarding what is detected, but unless stereo sensors are used, cannot provide accurate information regarding where an obstacle is. Clearly, imaging and radar technologies complement one another. It is important to ensure that these imaging systems work well alone and that they can be integrated into driver-assistive systems as they are deployed. Camera systems including forward-looking infrared

(FLIR) and Super Dynamic Range Camera (SDRC) have been evaluated, with the conclusion that inexpensive camera systems cannot compete with infrared systems. Recent work focuses on integration of infrared (IR) data with global positioning system (GPS) data provided by geospatial database queries using OpenSceneGraph. The primary challenge of this work is to integrate two image sources with different resolutions. When the system is complete, it will be tested on the SAFELOW research vehicle.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004056

Multiuse, High-Accuracy, High-Density Geospatial Database

Status: In progress

High-accuracy (2–8 cm) DGPS and high-accuracy (5–20 cm) geospatial databases are the primary components of the IV Lab driver-assistive systems. In addition to vehicle-based systems, the IV Lab geospatial database has been used in other applications—for instance, for a new intersection decision support (IDS) project in which radar sensors are used to determine the state of an intersection as a first step in warning drivers when it is unsafe to enter an unsignalized intersection. For this application, the geospatial database is used to improve the ability of the radar system to determine whether a target represents a legitimate threat at the intersection.

The IV Lab geospatial database was designed and optimized for vehicle applications, and as such it provides real-time access to extremely accurate, dense geospatial data. Because of this optimization, however, its functionality in other applications is somewhat limited. As new applications arise (e.g., the need

to integrate high-accuracy geospatial data into a driving simulator), a more "global" approach to the geospatial database is required. This project proposes a redesign of the geospatial database and database manager and the development of a new front end to serve a wide application base.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005047

Quick Edge: Rapid Underbody Plow Cutting Edge Changing System

Status: In progress

Currently, cutting edges on snowplows are bolted to the plow blade with three or four fasteners. To ensure clear pavement plowing, substantial downward force is placed on the cutting edges, resulting in rapid wear and frequent replacement of the cutting edge. The process of changing cutting edges is time-consuming and tedious. Also, the limited space available forces mechanics to work in awkward positions and leads to back and joint injuries. This project explores an alternative to the current bolting process. The new system will be designed with the objective of reducing time and effort required in the change and decreasing the risk of injury compared to the current labor-intensive bolting process. The alternative system has been designed and fabricated, and presented to the Minnesota Department of Transportation.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004058



Inexpensive Automated Bus Markup (Indoor Location) System

Status: Newly funded

Bus "markup" refers to the process of determining the location (aisle, position in aisle) of every bus in a bus garage. Currently, a Metro Transit employee performs this task by walking the aisles in a bus garage and recording the position of each bus in the garage area. Markup is done continuously for every shift of every day of every year in each bus garage—making it a tedious, expensive task ripe for automation. Metro Transit estimates that each bus garage requires a full-time equivalent employee to perform the markup task; when salary and benefits are factored in, bus markup becomes a very expensive proposition. Surprisingly, no off-the-shelf automated bus markup systems are on the market.

Metro Transit has investigated the automation of the markup task to improve operational efficiency and to reduce operational cost. This research proposes a two-phase project designed to use existing Metro Transit Wi-Fi infrastructure located in each of its bus garages to facilitate a low-cost, reliable, robust automated bus markup system. The goal is to design and implement a system in cooperation with Metro Transit in 18 months for a price less than the two-year salary and benefit cost of the five full-time equivalent employees currently performing bus markup duties.

Project URL: www.its.umn.edu/research/workplan/P2006036.html

Shashi Shekhar, Department of Computer Science and Engineering Decision Support System for Evacuation Route-Schedule Planning: Determining Optimal Network Configuration

Status: In progress

Evacuation route-schedule planning identifies paths to move populations to safe areas in the event of catastrophes, natural disasters, and terrorist attacks. Current approaches are based on assignment-simulation tools. However, the quality of solutions from these tools depends on the logical configuration of the transportation network. Currently, engineering judgment is used to select logical network configuration. This project aims to develop algorithms and software tools to determine effective logical network configuration given the physical transportation network and evacuation traffic demand—a challenging research problem due to the exponential combinatorial search space of possible solutions. The new algorithms will be integrated with assignment simulation tools and evaluated under specific scenarios. This research will provide new tools to help Mn/DOT find the optimal logical network configuration to supply to assignment simulation models toward effective evacuation route-schedule planning.

Recent research focuses on contraflow (reversing the direction of inbound roads) as a tool for reducing evacuation time. Contraflow is considered a potential remedy to solve congestion during evacuations. Currently available contraflow configuration algorithms only address a single-source/multiple-destinations situation. These approaches cannot

handle a multiple-sources problem, which is harder due to conflicts across the optimal paths from different sources. In this project, evacuation situations are formally defined using graph and flow theory, and the contraflow problem is shown to be NP-complete. This research proposes two capacity-aware global contraflow heuristics that produce contraflow configuration in the presence of conflicts among routes preferred by different source nodes. These heuristics are evaluated using synthetic networks as well as real-world datasets. In addition, an algebraic cost model is developed. Experimental results show that these contraflow heuristics can reduce evacuation time by 30 percent or more.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004006

Stephen Simon, Law School In-Vehicle Driver Assistance for Teenagers

Status: In progress

Approximately 6,000 teenagers die on U.S. roads every year. Although teenagers make up only 4.6 percent of all licensed drivers, they are involved in nearly 13 percent of all fatal crashes.

A possible approach to mitigating the incidence of teenage driver crashes and fatalities is through the use of in-vehicle technology. The Teen Driver Support System (TDSS) aims to address five primary contributing factors associated with the majority of teen fatal crashes: speeding, seat belt use, alcohol impairment, driver inattention/distraction, and driver inexperience. This will be implemented using a combination of what is called forcing, feedback, and/or reporting functions. Forcing functions will be in the form

of ignition interlocks to enforce seat belt compliance and sober driving. A feedback function will provide real-time tutoring and warnings about illegal or unsafe speeds. A reporting function will record vehicle information for parents to review and supervise (and enforce) teen driver performance. An evaluation of past and present commercially available in-vehicle systems has identified a number of deficiencies; these systems are too passive and do not offer the best possible technological solution.

Validation of the TDSS will be accomplished over a three-phase program. The first phase of the project (design and development of a prototype TDSS system) is underway with funding from the ITS Institute. A speed-limit feedback and reporting system has been developed, and testing of the speed-limit notification system is currently underway. Alcohol interlock systems are commercially available and can be integrated into the system. Considering the cost, however, the alcohol interlock component would be reserved for teen drivers with preexisting alcohol-related convictions. Since seat belt interlock is no longer commercially available, a method of integrating a low-cost seat belt interlock is being explored.

An outline has been drafted for two additional phases: 1) the design and evaluation of human interfaces for the selected feedback and reporting systems used to modify driving behavior (which will be based on a population of teenagers using a driving simulator), and 2) a subsequent multi-vehicle field operational test to evaluate the benefits of a TDSS. The goal of this research is to develop and validate a new support system that can be used by teen drivers, parents, the

insurance industry, and government (through public policy, graduated licensing, etc.) to effect significant improvements in the near future.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004057



TECHNOLOGIES FOR MODELING, MANAGING, AND OPERATING TRANSPORTATION SYSTEMS

Gary Davis, Department of Civil Engineering

A Case-Controlled Study of Driving Speed and Crash Risk

Status: In progress

In the United States, the imposition and subsequent repeal of the 55 m.p.h. speed limit has led to an increasingly energetic debate concerning the relationship between speed and the risk of being in a fatal crash. In addition, research done in the 1960s and 1970s suggested that crash risk is a U-shaped function of speed, with risk increasing as one travels both faster and slower than what is average on a road. Debate continues as to the causes of this relationship, and there is reason to suspect that it may be an artifact of measurement error and/or mixing of different crash types.

For this study, the researchers undertook two case-control analyses of run-off-road crashes, one using data collected in Adelaide, Australia, and the other using data from Minnesota. In both analyses the speeds of the case vehicles were estimated using accident reconstruction techniques while the speeds of the controls were measured for vehicles traveling the crash site under similar conditions. Bayesian relative risk regression was used to relate speed to crash risk, and uncertainty in the case speeds was accounted for by treating these as additional unknowns with informative priors. Neither data set supported the existence of a U-shaped relationship, although crash risk clearly tended to increase as speed increased. The resulting logit model was then used to estimate the probability that a given speed could be considered a causal factor for each of the 10 Minnesota crashes.

Project URL: [www.its.umn.edu/research/projectdetail](http://www.its.umn.edu/research/projectdetail.pl?id=2001032)

[.pl?id=2001032](http://www.its.umn.edu/research/projectdetail.pl?id=2001032)

Bus Signal Priority Based on GPS and Wireless Communications

Status: In progress

The Minneapolis-St. Paul metropolitan transit agency has installed global positioning system (GPS) equipment in transit vehicles for the purpose of monitoring vehicle locations and schedules in order to provide more reliable transit services. This research project evaluates the potential use of vehicle-mounted GPS to develop a transit signal priority system that improves the efficiency of transit. Bus signal priority has been implemented in several U.S. cities to provide more reliable travel and improve customer ride quality. Current signal priority strategies implemented in various U.S. cities have mostly used sensors to detect buses at a fixed or at a preset distance away from the intersection. Signal priority is usually granted after a preprogrammed time offset after detection. The strategy developed in this research will consider the bus's timeliness with respect to its schedule, location, and speed.

Project URL: [www.its.umn.edu/research/projectdetail](http://www.its.umn.edu/research/projectdetail.pl?id=2005038)

Identification of Causal Factors and Potential Countermeasures for Fatal and Severe Rural Crashes

Status: In progress

Developing effective strategies for achieving a zero-fatality goal requires understanding the exact causes of traffic crashes. This project addresses the issue of causation first by reconstructing a set of run-off-road crashes and determining if the presence of barriers compliant with NCHRP 350 Test level 3 would have

prevented the crashes, and second, by conducting an expert assessment of the presence of specified causal factors (and susceptibility to countermeasures) for a larger sample of fatal rural crashes.

Project URL: [www.its.umn.edu/research/projectdetail](http://www.its.umn.edu/research/projectdetail.pl?id=2003014)



Safety Effect of Left-Turn Phasing Schemes at High-Speed Intersections

Status: In progress

Selection of appropriate phasing for left turns at lower-volume intersections often requires making a trade-off between the delay imposed on left-turners versus the increased crash risk associated with permissive treatments. At present it is unclear what traffic conditions warrant protected treatments, but this project seeks to reduce this uncertainty by 1) estimating crash reduction factors associated with protected and protected/permitted left-turn treatments, 2) testing whether or not these factors vary with opposing approach speed, and 3) developing a simulation model for computing left-turn conflict rates as functions of opposing traffic conditions.

Project URL: [www.its.umn.edu/research/projectdetail](http://www.its.umn.edu/research/projectdetail.pl?id=2002043)



Cross-Median Crashes: Identification and Countermeasures

Status: Newly funded

A cross-median crash occurs when a vehicle leaves its traveled way, completely crosses the median dividing the highway's directional lanes, and collides with a vehicle traveling in the opposite direction. AASHTO's *Roadside Design Guide* recognizes two countermeasures for prevention of cross-median crashes: medians wide enough to provide adequate "clear zones" where a driver can stop or regain control of the vehicle before crossing into the opposing traffic stream, and installation of median barriers when medians are less than 10 meters wide and annual daily traffic is greater than 20,000 vehicles per day.

As with any safety countermeasure, installation should begin with those locations showing the greatest expected benefits. This project will first review the state of the art in median-crossing crash protection through a literature review and a survey of current practices. This will be followed by statistical modeling of the frequency of median-crossing crashes in Minnesota, with the object of identifying those locations where countermeasure installation is most likely to pay off. Finally, this project will investigate method(s) for predicting the crash reduction benefits of median barrier treatments on particular highway sections.

Project URL: [www.its.umn.edu/research/projectdetail](http://www.its.umn.edu/research/projectdetail.pl?id=2005057)

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Demoz Gebre-Egziabher, Department of Aerospace Engineering and Mechanics RPV/UAV Surveillance for Transportation Management and Security

Status: In progress

This research is aimed at developing the capabilities required to investigate the technical and operational issues associated with using remotely piloted vehicles (RPVs) or uninhabited aerial vehicles (UAVs) for traffic monitoring. The outcome of this work will be a prototype flying platform, sensors, algorithms, and operational procedures that enable autonomous monitoring of highways and the capability to relay the information in real time to remotely located decision makers. To this end, the research team is developing a low-cost RPV instrumented with an inexpensive geo-referencing sensor suite and camera system.

The geo-referencing sensor suite consists of a WAAS-enabled GPS receiver for generating estimates of position and velocity. Attitude determination will be performed by a multi-antenna carrier-phase-differential GPS system. A dual camera system will be used to capture video images. The geo-referencing data and video images are transmitted via a data-link to a ground station and used for real-time highway infrastructure monitoring and pilot-in-the-loop control of the RPV. The ground station includes geo-referencing and video data archiving capabilities for playback purposes. Operational procedures that ensure that operations occur outside controlled airspace at all times will be developed. By monitoring vehicle cohorts, traffic parameters

useful to traffic management can be determined. The researchers will validate operation of the systems and procedures developed in a final capstone demonstration that will show how the navigation state vector of a ground vehicle can be estimated using remotely sensed data from an RPV.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005040

David Levinson, Department of Civil Engineering, and **Kathleen Harder**, College of Architecture and Landscape Architecture
Ramp Meter Delays, Freeway Congestion, and Driver Acceptance

Status: Completed (in FY05)

For this study, the researchers conducted several experiments using both the Computer Administered Stated Preference, or CASP, and Virtual Experience, or VESP, methodologies. Nominally, the same combinations of ramp meter waiting time and freeway travel time were tested in the first two parts of the CASP experiment (CASP-a and CASP-b) and in the first two experiments (VESP experiment #1 and VESP experiment #2). The combinations of time spent waiting at ramp meters and driving on the freeway that were presented in CASP-a were the same as the combinations of desired ramp meter waiting and driving times for VESP experiment #1. Similarly, the combinations of times presented in CASP-b were the same as the combined desired times for VESP experiment #2. However, it should be noted that there was some variation in the actual driving times from the desired times in the VESP experiments. This variation occurred because in the VESP experiments

the driving time was manipulated by varying the congestion level of the traffic in which the participants drove.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002018



David Levinson, Department of Civil Engineering
Improving the Estimation of Travel Demand for Traffic Simulation

Status: Completed (in FY05)

Many current traffic management schemes are tested and implemented using traffic simulation. An origin-destination (OD) matrix is an ideal input for such simulations. The underlying travel demand pattern produces observed link counts that could be used to reconstruct the OD matrix. An offline approach to estimate a static OD matrix over the peak period for freeway sections using these counts was proposed in this research. Almost all the offline methods use linear models to approximate the relationship between the on-ramp and off-ramp counts.

Previous work indicates that the use of a traffic flow model embedded in a search routine performs better than these linear models. In this research, that approach was enhanced using a microscopic traffic simulator, AIMSUN, and a gradient-based optimization routine, MINOS, interfaced to estimate an OD matrix. The problem is highly non-linear and non-smooth, and the optimization routine finds multiple local minima but

cannot guarantee a global minima. However, with a number of starting "seed" matrices, an OD matrix with a good fit in terms of reproducing traffic counts can be estimated. The dominance of the mainline counts in the OD estimation and an identifiability issue are indicated from the experiments. The quality of the estimates improves as the specification error, introduced due to the discrepancy between AIMSUN and the real-world process that generates the on-ramp and off-ramp counts, shrinks.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2001034

Measuring the Equity and Efficiency of Ramp Metering

Status: Completed (in FY05)

Ramp metering, which maintains smooth freeway mainline flow by limiting vehicle entry at entrance ramps, has been proposed and implemented in a number of metropolitan areas in and outside the United States to mitigate freeway congestion. This study sought to develop both efficient and equitable freeway ramp control strategies. Traffic conditions with and without ramp metering are evaluated on several representative freeways in the Twin Cities with a comprehensive set of performance measures. A unified theory for ramp metering is proposed based on a linear programming model of freeway traffic dynamics. The most efficient ramp control algorithm is found to be also the least equitable one. A novel control objective, minimizing weighted or perceived travel time, is therefore proposed to balance the efficiency and equity objectives of ramp metering. This research also developed a new family of applicable ramp metering strategies

that consider both efficiency and equity and are demonstrated in a microscopic traffic simulator.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2001010

The Value of Traveler Information for Motorists

Status: Completed (in FY05)

While there is a sizable body of literature on the benefits of travel information, most of it is based on theory or on simulations. This experiment analyzed results based on a field test of 117 drivers completing the same point-to-point trip in their own vehicles via five different routes. Participants traveled both arterial and freeway routes, assessed the travel information that was provided, evaluated the importance of the accuracy of the information, and charted their route preferences for various trip purposes. Researchers were not looking merely for perceived time savings but also for driver perception of the value of the time saved in order to make projections about whether drivers would be willing to pay for accurate travel updates to reduce overall cost, anxiety, and uncertainty while driving. Knowledge of how much users want to pay for Advance Travel Information System (ATIS) services is necessary for the design of sustainable for-profit private services or private/public partnerships.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004028

Panos Michalopoulos, Department of Civil Engineering
Accident Prevention Based on Automatic Detection of Accident-Prone Traffic Conditions (Phase I)

Status: In progress

Traditional measures to reduce

crashes include improved geometric design, congestion management strategies, and better driver education and enforcement. While such measures can be effective, they are often not feasible or are prohibitively expensive to implement. This realization, along with the increasing need to reduce crashes and their side effects, has recently led to proactive approaches to avoid their occurrence.

One of the most promising options gaining wide acceptance in recent years is the concept of detecting crash-prone flow conditions in real time and warning drivers when the probability of a crash is high in order to increase their attentiveness. Evidence suggests that when driver attentiveness increases, crashes decline in spite of poor driving and environmental conditions. However, research in identification and detection of crash-prone traffic conditions is embryonic; for example, demonstration that such conditions actually exist is still lacking, let alone a methodology for effective detection and system deployment.

This research aims to identify and develop a real-time algorithm for detecting traffic flow conditions associated with increased crash probabilities as well as a general methodology for identifying the crash mechanism in such freeway sections. To study this problem, the freeway section with the highest crash occurrence in the state was selected for observation and instrumented with a unique array of sensors and surveillance equipment. Several state-of-the-art detection and surveillance stations were designed, assembled, and deployed, generating an unparalleled database of detailed traffic measurements as well as a record of crashes in progress (visual and quantitative).

Based on this complete view of the problem, the researchers were able to identify real-time measurements that reliably describe crash-prone traffic conditions as well as determine the individual causes of such conditions. The results can be used in the design and deployment of driver warning systems as well as other active measures aimed at reducing risk in crash-prone areas.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003031



Development of Portable Wireless Measurement and Observation Station

Status: In progress

For this project, the researchers designed, assembled, and deployed a temporary detection and surveillance system to collect real-time data on traffic conditions. This information is critical in construction, advanced traffic management systems, advanced traffic information systems, and other design and operational activities. Because traditional, permanent systems collect data by sensors in the pavement and transmit it through land-based communications, this equipment is subject to failure in construction areas. Through advancements in wireless technology, the developed system integrates machine vision sensors to collect data, compress digital video for surveillance, and use wireless communications for information retrieval and remote

control. This new system can be added to current installations or used to create temporary traffic-monitoring systems.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002030

Development of Real-Time Traffic-Adaptive Crash Reduction Measures for the Westbound I-94/35W Commons Section

Status: In progress

According to Mn/DOT statistics, the westbound section of Interstate 94 at the I-94/35W commons south of downtown Minneapolis, Minnesota, has the highest crash rate in the Twin Cities. In an ongoing project related to crash prevention and the detection of crash-prone conditions, this site was heavily instrumented and observed, and detailed traffic measurements were analyzed. Data showed that these incidents occur under certain traffic conditions that can be detected prior to a crash.

This project will capitalize on the results of the ongoing research by utilizing the available techniques for the early detection of crash-prone conditions to develop a traffic calming/driver warning system for reducing crashes. The system will be specifically tuned for maximum effectiveness on the I-94 section. The goals of this first phase will be to 1) define relevant solutions based on available technologies and site characteristics; 2) implement the designs in an appropriate visualization environment; and 3) perform a preliminary evaluation and prioritization of the proposed solutions. The most promising solutions will later undergo thorough human factors analysis (e.g., driving simulator studies). Work will commence on the development of new and improved microscopic

simulation models. These models should overcome the current model deficiency—the inability to emulate unsafe driving behavior—and will be capable of evaluating traffic safety solutions based on intelligent transportation systems approaches.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005056

Employment of the Traffic Management Laboratory for Improving the Stratified Metering Algorithm (Phase III)

Status: Newly funded

This project is a continuation of previous research related to testing and evaluating the effectiveness of the stratified ramp metering strategy through rigorous microscopic simulation. The stratified ramp metering strategy has been proven to be generally effective in keeping ramp wait times below the maximum allowed for each ramp after one year of field operation and a preliminary evaluation. However, some inherent limitations of the strategy need to be further explored. This research project aims to attack these limitations by developing a credible, efficient, and feasible methodology that can balance the control objectives of freeway performance and ramp delays and provide more accurate online ramp-queue size estimation. All the enhancements and improvements to the stratified ramp control strategy will be computationally feasible and their effectiveness will be assessed by comparison with the current prototype version using microscopic simulation.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005044



Employment of the Traffic Management Laboratory for the Evaluation and Improvement of Stratified Metering Algorithm (Phase IV)

Status: Newly funded

This proposal is a continuation of the ongoing project related to improving and evaluating the effectiveness of Mn/DOT's new stratified zone metering (SZM) strategy. From field operations and offline evaluation, the improved SZM strategy was deemed effective in meeting the maximum ramp delay objective, but at the expense of the freeway and system performance as expected. However, the strategy can be further improved in several ways. This research aims at addressing the most promising improvements by developing an efficient and streamlined optimization methodology to identify the best control parameter set for the strategy based on site and demand characteristics. Currently these parameters are estimated by trial and error and are constant for the entire freeway system.

Additionally, this research aims to produce a more reliable ramp-demand prediction technique and an improved location-dependent bottleneck capacity estimation methodology based on real-time traffic conditions. All the enhancements and improvements to the SZM strategy will be computationally feasible and their effectiveness will be assessed compared to the current prototype

version through microscopic simulation to avoid costly, uncertain, and time-consuming field-testing as well as the disrupted traffic flow.

Project URL: www.its.umn.edu/research/database.html

Streamlining of the Traffic Modeling Process for Implementation in the Twin Cities Freeway Network

Status: In progress

This project is attempting to streamline the traffic modeling process for practical implementation, thereby improving Mn/DOT engineers' productivity in view of the new federal requirements for the design and planning of roadway improvements. Streamlining will also improve decision making and allow more widespread use of simulation internally for design, planning, operations, maintenance, and construction.

As part of this project, several rudimentary tools were developed to accelerate the simulation process; in the process, it became clear that better tools for obtaining high-quality data for simulation purposes were required. In collaboration with Mn/DOT's modeling group, the research team has developed an efficient methodology for detecting and correcting erroneous freeway loop detector data (temporal outliers, spatial discrepancies, locked-on data, missing data, stuck data, etc.). This methodology includes an optimization-based algorithm for balancing freeway spatial discrepancies. The methodology has been successfully implemented as computer software called TradaX, which can greatly facilitate and streamline the traffic input preparation for microsimulation packages such as AIMSUN, CORSIM, or PARAMICS. The team is currently working with

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Mn/DOT engineers to enhance the TradaX program by extending its functionality and improving the user interface. The enhanced TradaX program will include an improved arterial intersection demand balancing algorithm, and will be extensively tested using various geometry configurations.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004030

Enhanced Microsimulation Models for Accurate Safety Assessment of Traffic Management ITS Solutions

Status: Newly funded

Traffic simulation is increasingly becoming the tool of choice for evaluating new geometric designs as well as traffic control strategies. In fact, FHWA now requires every new project involving freeway reconstruction to be first evaluated through microscopic simulation. Unfortunately, where safety concepts are concerned, and even on evaluating the safety aspects of new geometric designs, current simulators are incapable of performing the task. The reason rests in the fundamental design of the underlying car-following models. All these different models have one common feature: they can only emulate the driving behavior of perfect drivers. It is impossible to emulate the actual "less than perfect" everyday driving behavior and the risk associated with the act of driving, therefore resulting in collision-free simulations.

The goal of this research is to expand, or create if necessary, traffic flow models capable of accurately replicating driving behavior with all its risks and imperfections. The research will capitalize on already collected detailed traffic data from actual freeway crashes. Concepts

such as less-than-adequate reaction times, improper selection of headways, and poor visibility and distractions will be introduced to the improved car-following models. The outcome of this research will be used to emulate the occurrence of real-world crash-prone conditions as well as normative driving behaviors in collision-free situations, and thus facilitate the assessment of freeway safety concepts at the high-definition microscopic level.

Project URL: www.its.umn.edu/research/workplan/P2006033.html

Frank Douma, Humphrey Institute of Public Affairs

Developing ITS to Serve Diverse Populations

Status: In progress

In 2003, the State and Local Policy Program (SLPP) at the University of Minnesota's Humphrey Institute of Public Affairs began research into how intelligent transportation systems (ITS) technologies can be used to deliver transportation services to an increasingly diverse population in Minnesota. The objective of this research is to identify the nature of the gap between the emerging needs and existing services, and to propose ways of using technology to bridge the gap, both in terms of providing better transportation options and in reducing the cost of these options.

Using the information obtained from emerging demographic data, the 2003 study focused on identifying transportation challenges and opportunities for several different populations, with a particular focus on those that do not or cannot drive. This project continues the theme through a series of analyses of ITS applications that appear most promising to improve mobility and access for Minnesota's increasingly diverse population. These applications include technologically advanced community-based transit, car sharing, use of ITS to implement value pricing through conversion of a high-occupancy vehicle (HOV) lane to a high-occupancy toll (HOT) lane, and evaluation of Web-based Advanced Traveler Information Systems.

As of June 2005, work is ongoing in all of these tasks. Preliminary findings indicate that car sharing could have a positive impact on the transportation disadvantaged if subsidized. Work continues on the

nature and size of that subsidy. In addition, a car-sharing program has started in the Twin Cities, and some data from that program are being collected. Other early findings show support for the HOV conversion across all income levels and gender. Analysis of a comprehensive survey on "non-traditional" community-based transit (CBT) providers continues, and innovations in CBT regulation that can promote collaboration have been reviewed. Finally, work continues on the ATIS evaluation.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004047

Kevin Krizek, Humphrey Institute of Public Affairs

Understanding the Potential Market of Metro Transit's Ridership and Services

Status: In progress

Metro Transit faces the challenge of serving a diverse audience that includes people of all ages and backgrounds with varying riding habits, needs, and preferences.

This research has two main goals. The first is to provide better knowledge of the composition of the travel market in the Twin Cities metropolitan area, in particular those inclined toward transit-related services. The foundation of this research comes from available data collected by Metro Transit, such as the rider and non-rider surveys that have been collected over the past several years. The former provides information on existing use; the latter gives insights into how to better attract people who are not currently using the services provided by Metro Transit. Where applicable, such information will be complemented with other available data to provide more in-depth analysis. This includes, but is not limited to, marrying the

rider and non-rider data with surveys available from Metro Commuter Services, the Travel Behavior Inventory, general surveys of the Guaranteed Ride Home program, and urban form data (e.g., density, employment locations).

The second goal of this research is to use the above information in concert with knowledge about available technologies to comment on how ridership could possibly be enhanced. This research project carries out market segmentation of travelers, which can then be used to point to instances where additional data/information should be targeted (through more advanced data collection means using available technology) as well as strategic planning of services according to these market segments. A final report will summarize the research and provide recommendations to Metro Transit for future data collection efforts.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004060



Lee Munnich, Humphrey Institute of Public Affairs

Sustainable Technologies Applied Research Initiative FY04

Status: In progress

The STAR project is investigating the intersection of various networks—including ITS-infused transportation networks—and how they interact with physical places, as well as the changes that are occurring among and between networks and the

dimensions (e.g., access, activity) that concern the STAR researchers. Year three activities have led to the following focus areas for Year Four.

Spatial Impacts (Task 1)

A study was completed of the spatial location of information workers in six metropolitan areas—Atlanta, Austin, Denver, Houston, Phoenix, and Minneapolis-St. Paul—based on data from the Census Transportation Planning Package (CTPP) for 1990 and 2000. The study found that the workplace locations of information workers were more spatially concentrated than other workers in all six metropolitan areas. The residential locations of information workers were not significantly more concentrated, and information workers tend to spend more time commuting than other workers. Research is continuing on the diffusion processes of computer/telecommunications innovations and their links to urban spatial structure. Researchers have acquired modeling software and are concentrating on linking systems-dynamics models with agent-based cellular automata mode.

Researchers will also analyze the impact of Internet-based shopping on the travel preferences of people and quantify the impact the Internet has on trip-making decisions.

Modeling of Wireless Rural EMS Performance (Task 2)

Researchers are devising and testing a model for assessing end-to-end performance of mobile emergency medical systems (EMS). Analysis has focused on technical (data exchange) as well as the organizational policies that surround information-sharing arrangements. Interviews and case studies conducted both locally and nationally provided an understanding of the

role that ITS and related technology can play in enhancing the operational and management performance of transportation operations communications/EVMS centers in rural areas, including but not limited to response times.

Industry Clusters (Task 3)

Researchers are exploring the link between industry clusters and ITS technologies, with specific emphasis on related policy issues. Prior project work involved a study of two of northwestern Minnesota's vibrant rural clusters—the recreational transportation equipment and wood products clusters—and the extent to which member firms in each cluster have incorporated information and communication technologies, including ITS. ITS technologies were found to be necessary but not sufficient for rural economic success. Year-five focus areas will include presenting a TRB paper concept to state and/or regional transportation planning organizations; requesting feedback specifically on the applicability of the ITS/cluster framework for designing and modifying regional ITS architectures; seeking input on upcoming projects or emerging problems that could serve as a pilot program in which the ITS/cluster concept may be used to inform the planning process; and using this feedback to target subsequent year-five efforts, ideally in the form of a partnership with Mn/DOT or a comparable transportation planning organization.

Networks and Productivity (Task 4)

Researchers are continuing to examine the relationships between network supply and travel demand and describe a road development and degeneration mechanism microscopically at the link level. They

confirmed the hypothesis that road hierarchy is an emergent property of transportation networks and discovered the underlying reasons. In addition, the long-run impacts of alternative pricing, investment, and management policies on network growth were examined by several measures of effectiveness. Findings suggest that the benefits of marginal cost pricing are sensitive to the distribution of toll revenue. The issue of optimal organizational structure for road networks was also explored. The next phase will focus on the development of an agent-based travel demand model that is structurally more consistent with the network dynamics model than sequential-demand models.

Education Forums, Outreach (Task 5)

In addition to convening former and current research assistants in Minneapolis and Washington, D.C., to provide insight into the experience of the new transportation professional, the researchers convened a workshop of leading scholars and practitioners on "Time-Critical Information Services" in April 2005. This workshop, held at the National Center for Digital Government at Harvard University's John F. Kennedy School of Government, explored the technology, organizational, and policy dimensions of electronic governmental and emergency response services. Researchers will continue to conduct outreach to local and national decision makers and educators.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004037

Selected publications

Alexander, L., Cheng, P., Donath, M., Gorjestani, A., Newstrom, B., Shankwitz, C., and Trach, W. (2004). DGPS-based lane assist system for transit buses. *Proceedings of the IEEE Conference on Intelligent Transportation Systems (ITS)*.

Atev, S., Masoud, O., Janardan, R., and Papanikolopoulos, N. (2005). A collision prediction system for traffic intersections. *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*.

Atev, S., Masoud, O., Janardan, R., and Papanikolopoulos, N. (2005). A collision prediction system for traffic intersections. *Proceedings of the International Conference on Robotics and Automation (ICRA)*.

Atev, S., Masoud, O., and Papanikolopoulos, N. (2004). Practical mixtures of Gaussians with brightness monitoring. *Proceedings of the 7th International IEEE Conference on Intelligent Transportation Systems (ITSC 2004)*.

Bageshwar, V., Garrard, W., and Rajamani, R. (2004). Model predictive control of transitional maneuvers of adaptive cruise control vehicles. *IEEE Transactions on Vehicular Technology*.

Bemat, E., Cadwallader, M., Rakauskas, M., Ward, N., Collins, P., and Patrick, C. (2004). Effects of intoxication on attention allocation in a naturalistic driving environment. *Psychophysiology Research*.

Bird, N., Masoud, O., Papanikolopoulos, N., and Isaacs, A. (2005). Detection of loitering individuals in public transportation areas. *IEEE Transactions on Intelligent Transportation Systems (ITS)*.

Boer, E., Ward, N., Manser, M., and Kuge, N. (2005). Driver-model-based assessment of behavioral adaptation. *Proceedings of the Journal of the Society of Automotive Engineers of Japan (JSAE) Annual Conference*.

Boer, E., Ward, N., Manser, M., Yamamura, T., and Kuge, N. (2005). Driver performance assessment with a car following model. *Proceedings of the Annual Driver Assessment Conference*.

Capo, S., Follin, E., Gallee, G., Ward, N., Easterlund, P., and Longhurst, G. (2004). Real-time eye movement analysis into driving simulators. *Proceedings of the Eighth Driving Simulator Conference*.

Creaser, J., Lees, M., and White, C. (2004). The effect of insight and error-based feedback on drivers' following behavior and confidence. *Human Factors and Ergonomics Society*.

Digham, F., and Alouini, M.S. (2004). Variable rate variable power MFSK



Mohamed-Slim Alouini

4. *IEEE Transaction on Wireless Communications*.

Domeich, M., Whitlow, S., Ververs, P., Carciofini, J., and Creaser, J. (2004). Closing the loop of an adaptive system with cognitive state. *Human Factors and Ergonomics Society*.

Ganguli, A., and Rajamani, R. (2004). Tractable model development and system identification for longitudinal vehicle dynamics. *Journal of Automobile Engineering, Proceedings of the Institution of Mechanical Engineers, Part D*.

Gohl, J., Rajamani, R., Alexander, L., and Starr, P. (2004). Active roll mode control implementation on a narrow tilting vehicle. *Vehicle System Dynamics*.

Gugerty, L., Rakauskas, M., and Brooks, J. (2004). Effects of remote and in-person verbal interactions on verbalization rates and attention to dynamic spatial scenes. *Accident Analysis and Prevention*.

Guo, Y., and Dourna, F. (2005). Intelligent transportation systems and other technological assistance used. *Compendium of Papers for 84th Annual Meeting of the Transportation Research Board (TRB)*.

Hahn, J., Rajamani, R., You, S., and Lee, K. (2004). Real-time identification of road bank angle using differential GPS. *IEEE Transactions on Control Systems*.

Horan, T., Abhichandani, T., and Hilton, B. (2005). Evaluating trip planning quality in use: prototyping a metric for diverse trips. *Compendium of Papers for 84th Annual Meeting of the Transportation Research Board (TRB)*.

Horan, T., McCabe, D., Burkhard, R., and Schooley, B. (2005). Performance information systems for emergency response: field examination and simulation of end-to-end rural response systems. *Journal of Homeland Security and Emergency Management*.

Hossain, J., Alouini, M.S., and Bhargava, V.K. (2005). Multi-user opportunistic scheduling using power controlled hierarchical constellations. *Proceedings of the Mobile and Wireless Communications Summit*.

Hourdakis, J., Michalopoulos, P., and Morris, T. (2004). Deployment of wireless, mobile detection and surveillance for data intensive applications. *Transportation Research Record*.

Jianping, P., and Davis, G. (2005). Bayesian reconstruction of median-crossing crashes and potential effectiveness of cable barriers. *Com-*

pendium of Papers for the 84th Annual Meeting of Transportation Research Board (TRB).

Kuge, N., Ward, N., Manser, M., and Boer, E. (2004). A study on quantification of driver workload in car following. *Proceedings of IEEE Conference*.

Laberge, J., and Ward, N. (2004). Cannabis and driving: research needs and policy issues. *Journal of Drug Use*.

Laberge, J., Ward, N., Manser, M., Karatekin, and C, Yonas, A. (2005). Driving skills among ADHD drivers: preliminary research. *Proceedings of the Third International Conference on Traffic and Transport Psychology (ICTTP)*.

Lawton, R., and Ward, N. (2005). A systems analysis of a fatal crash. *Journal of Accident Analysis and Prevention*.

Levinson, D., Harder, K., Bloomfield, J., and Winiarczyk, K. (2005). *Ramp meter delays, freeway congestion, and driver acceptance*. CTS 05-02, Center for Transportation Studies, University of Minnesota.

Lu, Q., George, B., and Shekhar, S. (2005). Capacity constrained routing algorithms for evacuation planning: a summary of results. *Proceedings of the Ninth International Symposium on Spatial and Temporal Databases (SSTD05)*.

Manser, M., Ward, N., Kuge, N., and Boer, E. (2004). Influence of a driver support system on situation awareness in information processing in response to lead vehicle braking. *Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting*.

Manser, M., Ward, N., Kuge, N., and Boer, E. (2004). The influence of distraction on driver behavior and safety in critical response events: from theoretical construct to driver training application. *Proceedings of the Third International Conference on Traffic and Transport Psychology*.

Masoud, O., and Papanikolopoulos, N. (2004). Using Geometric Primitives to Calibrate Traffic Scenes. *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2004)*.



Michael Manser

Menon, A., Gorjestani, A., Shankwitz, C., and Donath, M. (2004). Road-side range sensors for intersection decision support. *Proceedings of the IEEE Conference on Intelligent Transportation Systems (ITS)*.

Piyabongkarn, D., Keviczky, T., and Rajamani, R. (2004). Active direct tilt control for stability enhancement of a narrow commuter vehicle. *International Journal of Automotive Technology, Special Issue on Intelligent Vehicle Systems*.

Piyabongkarn, D., Rajamani, R., and Greminger, M. (2005). The development of a MEMS gyroscope for absolute angle measurement. *IEEE Transactions on Control Systems Technology*.

Piyabongkarn, D., Sun, Y., Rajamani, R., Sezen, A., and Nelson, B. (2005). Travel range extension for a MEMS electrostatic actuator. *IEEE Transactions on Control Systems Technology*.



Rajesh Rajamani

Rajamani, R., and Cho, Y. (2004). On stability radius and state feedback. *Control and Intelligent Systems Journal*.

Rajamani, R., and Ganguli, A. (2004). Sensor fault diagnostics for a class of nonlinear systems using linear matrix inequalities. *International Journal of Control*.

Rakauskas, M., Gugerty, L., and Ward, N. (2004). Effects of cell phone conversation on driving performance with naturalistic conversations. *Journal of Safety Research*.

Rakauskas, M., Ward, N., Gorjestani, A., Shankwitz, C., and Donath, M. (2005). Evaluation of a DGPS driver assistive system for snowplows and emergency vehicles. *Traffic and Transport Psychology*.

Shekhar, S., and Lu, Q. (2004). Evacuation planning for homeland security. *Minnesota Homeland Security and Emergency Management Newsletter*.

VanTassel, W., Dennis, M., and Manser, M. (2005). Beyond the norm with instructor preparation: Hands On Experiences. *American Driver Trainer Safety Educators Association Chronicle*.

VanTassel, W., and Manser, M. (2005). Front, rear, and all wheel drive: a comparison of the advantages and disadvantages of the basic drive-train layouts. *American Driver Trainer Safety Educators Association Chronicle*.

Veeraraghavan, H., Atev, S., Bird, N., Schrater, P., and Papanikolopoulos, N. (2005). Driver activity monitoring through supervised and unsupervised learning. *Proceedings of the IEEE Intelligent Transportation Systems Conference (ITSC 2005)*.

Veeraraghavan, H., Papanikolopoulos, N. (2004). Combining multiple tracking modalities for vehicle tracking at traffic intersections. *Proceedings of the International Conference on Robotics and Automation (ICRA 2004)*.

Veeraraghavan, H., Schrater, P., and Papanikolopoulos, N. (Submitted). Adaptive geometric templates for feature matching. *Proceedings of the International Conference of Computer Vision*.

Vitthaladevuni, P.K., Alouini, M.S., and Kieffer, J. (2004). Exact BER computation for the cross 32 QAM constellation. *IEEE Transactions on Wireless Communications*.

Wade, M. (2005). Forward looking blindspots: A report of A-pillar induced field-of-view obstruction and driver performance in a simulated rural environment. *Advances in Transportation Studies: An International Journal*.

Wambecke, B., and Shield, C. (2004). Development length of glass fiber reinforcing bars in concrete. *American Concrete Institute Structural Journal*.

Wang, J., Alexander, L., and Rajamani, R. (2004). Friction estimation on highway vehicles using longitudinal measurements. *American Society of Mechanical Engineers (ASME) Journal of Dynamic Systems, Measurement and Control, Special Issue on Sensors*.

Wang, J., Rajamani, R. (2004). Should adaptive cruise control systems be designed to maintain a constant time-gap between vehicles? *IEEE Transactions on Vehicular Technology*.



Nic Ward

Wang, J., and Rajamani, R. (2004). The impact of ACC systems on highway safety and traffic flow. *Journal of Automobile Engineering / Proceedings of the Institution of Mechanical Engineers, Part D*.

Ward, N. (2005). Review of crash risk and driving performance of drivers with clinical mental and personality disorders. *Compendium of papers from the 84th Annual Meeting of the Transportation Research Board (TRB), Washington, D.C.*

Ward, N., Alexander, L., Cheng, P.,

Gorjestani, A., Newstrom, B., Olson, C., Shankwitz, C., Trach, W., and Donath, M. (2004). A demonstration of a vision enhancement system for state patrol vehicles. *Intelligent Transportation Systems (ITS) Journal*.

Ward, N., Gorgestani, A., Shankwitz, C., and Donath, M. (2004). A preliminary demonstration study of the usability of a vision enhancement system for state patrol vehicles. *Intelligent Transportation Systems (ITS)*.

Ward, N., Shankwitz, C., Gorgestani, A., Donath, M., Waard, D., and Boer, E. (2004). Bus rapid transit (BRT) in Minnesota: lane support system. *Proceedings of the Third International Conference on Traffic and Transport Psychology*.

Xin, W., Michalopoulos, P., Hourdakis, J., and Lau, D. (2004). Minnesota's new ramp control strategy: design overview and preliminary assessment. *Transportation Research Record*.

Yang, J.S. (2005). A neural network-based simultaneous perturbation stochastic approximation approach to traffic signal timing control. *School of Engineering and Applied Science (SEAS) Transactions on Systems*.

Yang, J.S. (2005). A neural network-based stochastic approximation approach to special events traffic signal timing control. *Proceedings of the Ninth World Multi-Conference on Systemics, Cybernetics, and Informatics*.



Jiann-Shiou Yang

Yang, J.S. (2005). Application of the Kalman filter to the arterial travel time prediction. *International Journal of Control and Intelligent Systems*.

Yang, J.S. (2005). Autoregressive integrated moving average modeling for short-term arterial travel time prediction. *Proceedings of the 2005 International Conference on Modeling, Simulation and Visualization Methods*.

Yang, J.S. (2005). Special events travel time prediction based on Kalman filter. *Proceedings of the Ninth World Multi-Conference on Systemics, Cybernetics, and Informatics*.

Yang, J.S. (2005). Travel time prediction using the GPS test vehicle and Kalman filtering techniques. *Proceedings of the 2005 American Control Conference*.

Zhu, H., Yu, X., Rajamani, R., and Stelson, K. (2004). Active control of glass panels for reduction of sound transmission through windows. *Mechatronics*.

ITS Presentations

Atev, S., Masoud, O., and Papanikolopoulos, N. (2004, October). Practical mixtures of Gaussians with brightness monitoring. 7th International IEEE Conference on Intelligent Transportation Systems (ITS). Washington, D.C.

Beegala, A., Hourdakos, J., and Michalopoulos, P. (2004). Methodology for performance optimization of ramp control strategies through micro-simulation. 84th Annual Meeting of the Transportation Research Board, Washington, D.C.

Bernat, E., Cadwallader, M., Rakauskas, M., Ward, N., Collins, P., and Patrick, C. (2004, October). Effects of intoxication on attention allocation in a naturalistic driving environment. Society for Psychophysiological Research's 44th Annual Meeting, Santa Fe, New Mexico.

Boer, E., Rakauskas, M., Ward, N., and Goodrich, M. (2005, June). Steering entropy revisited. Third International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Rockport, Maine.

Boer, E., Ward, N., Manser, M., and Kuge, N. (2005, May). Driver-model-based assessment of behavioral adaptation. Journal of the Society of Automotive Engineers of Japan (JSAE) Annual Conference, Yokohama, Japan.

Boer, E., Ward, N., Manser, M., Yamamura, T., and Kuge, N. (2005, June). Driver performance assessment with a car following model. Annual Driver Assessment Conference, Rockport, Maine.

Caird, J., Chisholm, S., Edwards, C., and Creaser, J. (2005, January). The effect of amber light onset time on older and younger drivers' perception response time (PRT) and intersection behavior. 84th Annual Meeting of the Transportation Research Board, Washington, D.C.

Capo, S., Follin, E., Gallee, G., Ward, N., Easterlund, P., and Longhurst, G. (2004, September). Real-time eye movement analysis into driving simulators. Eighth Driving Simulator Conference, Paris, France.

Creaser, J., and Ward, N. (2004, September). A human-centered approach to toward zero death (TZD). Toward Zero Deaths: Integrating Minnesota's Traffic Safety Agenda Conference, St. Cloud, Minnesota.

Donath, Max. (2004, November). Visionary map database requirements. Eleventh World Congress on Intelligent Transportation Systems (ITS), Nagoya, Japan.

Donath, Max. (2005, June). Intelligent vehicles: designing human centered systems for crash avoidance. IEEE Intelligent Vehicles Symposium, Las Vegas, Nevada.

Douma, F., Andrew, J. (2005, February). Using ITS to serve diverse populations: car sharing in the Twin Cities. Center for Transportation Studies Planning and the Environment Council Meeting, University of Minnesota, Minneapolis, Minnesota.

Harder, K. (2004, August). The effectiveness and safety of traffic and non-traffic related messages presented on changeable message signs. International Congress of Psychology, Beijing, China.

Harder, K. (2004, October). The effectiveness and safety of traffic and non-traffic related messages presented on changeable message signs (CMS). Annual Ohio Transportation Engineering Conference, Columbus, Ohio.

Harder, K. (2004, September). Aggressive driving: research findings and recommendations. Toward Zero Deaths: Integrating Minnesota's Traffic Safety Agenda Conference, St. Cloud, Minnesota.

Harder, K. (2004, September). Aggressive driving: research findings and recommendations. Intelligent Transportation Systems board meeting, Center for Transportation Studies, University of Minnesota, Minneapolis, Minnesota.

Harder, K. (2005, April). Aggressive driving: research findings and recommendations. Annual meeting of the Minnesota Alcohol Traffic Safety Association, St. Cloud, Minnesota.

Horan, T. (2005, March). Rural safety in Minnesota. Congressional Update for Congressman Oberstar, Cambridge, Minnesota.

Kuge, N., Ward, N., Manser, M., and Boer, E. (2004, September). A study on quantification of driver workload in car followings. IEEE Conference, Yokohama, Japan.

Laberge, J., and Ward, N. (2004, September). Driving skills amongst ADHD drivers. International Conference on Traffic and Transport Psychology, Nottingham, England.

Laberge, J., Ward, N., Manser, M., Karatekin, C., and Yonas, A. (2004, September). Driving skills amongst ADHD drivers: preliminary research. International Association of Applied Psychology Conference, Nottingham, England.

Levinson, D., and Zhang, Lei. (2005, January). Investing for reliability and security in transportation networks. 84th Annual Meeting of the Transportation Research Board, Washington, D.C.



David Levinson

Levinson, David. (2004, July). Agent-based modeling of search and learning behavior in travel decision-making. 10th World Conference on Transport Research, Istanbul, Turkey.

Levinson, D. (2005, August). Investing for robustness and reliability in transportation networks. Second International Symposium on Transportation Network Reliability, Christchurch and Queenstown, New Zealand.

Lu, Q., George, B., and Shekhar, S. (2005, August). Capacity constrained routing algorithms for evacuation planning: a summary of results. Symposium on Spatial and Temporal Databases (SSTD) Conference, Angra dos Reis, Brazil.

Lu, Q. (2004, September). Evacuation planning. Advanced Transportation Technologies Seminar Series, Center for Transportation Studies, University of Minnesota, Minneapolis, Minnesota.

MacIin, R. (2004, November). A traffic data warehousing scheme. 2004 Northland Advanced Transportation Systems Research Laboratories Research Day, Duluth, Minnesota.

Manser, M., Boer, E., Ward, N., and Kuge, N. (2005, September). Impact of ecologically valid haptic driver support on visual-sampling and multi-tasking strategies. Vision in Vehicles 11th Annual International Conference, Dublin, Ireland.

Manser, M., Ward, N., Kuge, N., and Boer, E. (2004, September). The influence of distraction on driver behavior and safety in critical response events: from theoretical construct to driver training application. Third International Conference on Traffic and Transport Psychology, Nottingham, England.

Manser, M., Ward, N., Kuge, N., and Boer, E. (2004, September). The influence of distraction on driver behavior and safety in critical response events: from theoretical construct to driver training application. International Association of Applied Psychology Conference, Nottingham, England.

Manser, M., Ward, N., Kuge, N., Boer, E. (2004, September). Influence of a driver support system on situation awareness in information processing in response to lead vehicle braking. 48th Annual Human Factors and Ergonomics Society Meeting, New Orleans, Louisiana.

Manser, M. (2004, July). History and evaluation of simulation. Annual Conference of the American Driver and Traffic Safety Education Association (ADTSEA) Conference, Portland, Oregon.

Manser, M. (2005, September). High fidelity driving simulator. 49th Annual Human Factors and Ergonomics Society Meeting, Orlando, Florida.

Manser, M. (2004, September). Emergency event performance of drivers: implications for driver education performance. 48th Annual Human Factors and Ergonomics Society Meeting, New Orleans, Louisiana.

Masoud, O., and Papanikolopoulos, N. (2004, October). Using geometric primitives to calibrate traffic scenes. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2004), Sendai, Japan.

Munnich, L., and Duncan, C. (2005, January). The value chain industry cluster in ITS planning. 84th Annual Meeting of the Transportation Research Board, Washington, D.C.



Lee Munnich

Nebiyuou, T. (2005, January). Trails, lanes, or traffic: value of different bicycle facilities using adaptive stated preference survey. 84th Annual Meeting of the Transportation Research Board, Washington, D.C.

Pei, J. (2005, January). Bayesian reconstruction of median-crashes and potential effectiveness of cable barriers. 84th Annual Meeting of the Transportation Research Board, Washington, D.C.

Rakauskas, M., Ward, N., Gorgestani, A., Shankwitz, C., and Donath, M. (2004, September). Evaluation of a DGPS driver assistive system for snowplows and emergency vehicles. Third International Conference on Traffic and Transport Psychology, Nottingham, England.

Rakauskas, M., Ward, N., Bernat, E., Cadwallader, M., Patrick, C., and Waard, D. (2005, June). Psychophysiological measures of driver distraction and workload while intoxicated. Third International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Rockport, Maine.

Rajamani, R. (2004, September). Measurement systems for estimation of tire-road friction coefficient on highway vehicles. Center for Transportation Studies Transportation Safety and Traffic Flow Council Meeting, Minneapolis, Minnesota.

Shankwitz, C. (2005, March). Intersection decision support. Mn/DOT Surveyors Conference, St. Paul, Minnesota.

Shankwitz, C. (2005, March). Intersection decision support. Northland Chapter of the ATSSA "How to" Conference, Fargo, North Dakota.

Stech, H. (2004, November). Modeling issues associated with sensor technologies for the non-destructive evaluation of timber bridges. 2004 Northland Advanced Transportation Systems Research Laboratories Research Day, Duluth, Minnesota.



Craig Shankwitz

Veeraraghavan, H., and Papanikolopoulos, N. (2005, April). Computer vision-based methods for data collection at traffic intersections. CTS 16th Annual Transportation Research Conference, St. Paul, Minnesota.

Veeraraghavan, H., and Papanikolopoulos, N. (2004, October). Combining multiple tracking modalities for vehicle tracking at traffic intersections. International Conference on Robotics and Automation (ICRA), New Orleans, Louisiana.

Ward, N., Shankwitz, C., Gorgestani, A., Donath, M., Waard, D., and Boer, E. (2004, September). Bus rapid transit (BRT) in Minnesota: lane support system. Third International Conference on Traffic and Transport Psychology, Nottingham, England.

Ward, N. (2005, January). Review of crash risk and driving performance of drivers with clinical mental and personality disorders. 84th Annual Meeting of the Transportation Research Board, Washington, D.C.

Ward, N. (2005, May). Design and safety implications of ATIS use with cell phones. Research Coordinators Meeting, Arden Hills, Minnesota.

Ward, N. (2005, May). Reducing crashes at rural intersections. Research Coordinators Meeting, Arden Hills, Minnesota.

Yang, J.S. (2005, April). Special events travel time prediction based on the Kalman filter. CTS 16th Annual Transportation Research Conference, St. Paul, Minnesota.

Zhang, N., Yang, N., Feng, Q., and Yang, J.S. (2004, November). Duluth entertainment convention center special events traffic flow study: mobility monitoring and performance measure via the dynamic travel time prediction. Northland Advanced Transportation Systems Research Laboratories Research Day, Duluth, Minnesota.



Education

The Institute's activities in education encompass a multidisciplinary program of coursework and experiential learning that reinforces the Institute's theme. The educational program includes the disciplines of computer science and engineering, electrical and computer engineering, civil engineering, mechanical engineering, human factors, public policy, and others.

By sponsoring and supporting varied educational initiatives for students, the Institute is generating interest in its core ITS science and technologies. These initiatives include developing new curriculum and courses, involving undergraduate and graduate students in research projects, sponsoring students to attend national conferences, presenting awards that recognize outstanding students, and offering research assistantships to help attract more students to the study of transportation. This section of the annual report highlights some of our efforts in the area of education.

Teams geared up for Intelligent Ground Vehicle Competition

With funding and guidance from the ITS Institute and its NATSRL program in Duluth, two University of Minnesota teams competed in this year's 13th Annual Intelligent Ground Vehicle Competition held in Traverse City, Michigan, for three days in June.

Thirty-seven teams from universities across the U.S. participated in three different segments of the competition: the autonomous challenge, vehicle design, and navigation. The first requires the driverless vehicle to negotiate an outdoor obstacle course under a prescribed time while staying within the five m.p.h. speed limit and avoiding the obstacles on the track. The second awards points based on the process the teams used to design their vehicles based on a written report, oral presentation, and inspection of the vehicle. The third requires the vehicle to navigate its way around obstacles in a field to reach as many waypoints as possible.

Students Eric Li and Shawn Brovold test their intelligent ground vehicle on campus before leaving for the national competition in Michigan.

Mechanical engineering students Shawn Brovold, Nathan Carlson, Eric Li, and Greg Rupp represented the University's Twin Cities campus with their robot, "G2," a redesigned version of the last team's vehicle, "Gopher."

G2 is equipped with three wheels: two snow-thruster tires for traction and steering in the front, and a pivot-mounted stabilizing wheel in the rear. Powered by two 1.1-horsepower servomotors, the 475-pound vehicle finds its way using an array of sensors. A forward-facing camera collects visual data, such as the location of potholes and boundary markers. A laser sensor scans in front of the vehicle and reports the location and size of obstacles, such as construction barrels, cones, and barricades. Navigation is achieved with the use of a DGPS unit and a digital compass. Collected data are then processed and interpreted by National Instruments' LabVIEW software, all without user input.

The team, which hadn't competed since 2001, was advised by ITS Institute director Max Donath, research scientist Vassilios Morellas of Honeywell, and Don Krantz, vice president of MTS Systems. While the \$10,000 grand prize could have been put to good use, the project rewarded team members in other ways, Brovold said. "It gives the students who work on the robot a real-world learning experience." Donath said the team should be proud of its top-ten place in the competition.

This year was the first in which students at the University's Duluth campus attempted to build a vehicle for the competition. The fact that they even qualified for the competition was a big success, said team members Brian Linder and Tony Moua.

They and fellow undergrads in the Department of Electrical and Computer Engineering undertook the project as part of the ECE's Senior Design Workshop. The workshop has been offered over the last four years by Drs. Rocio Alba-Flores and Fernando Rios-Gutierrez and other ECE faculty.

The vehicle, known as MARVIN (for Mobile Autonomous Robotic Vision-Aided Intelligent Navigator), consisted of a modified power-wheel base equipped with four



Rocio Alba-Flores, Tony Moua, Brian Linder, and Rami Haddad prepare their vehicle, MARVIN, for the Intelligent Ground Vehicle Competition in Michigan.

ultrasonic sensors, a video camera, digital compass, GPS unit, power supply, a laptop computer, and HC12 Mini-Dragon microcontroller. Information from the sensors is processed by the microcontroller and sent to the laptop. Using MatLab, the laptop uses the data from the camera as well as the microcontroller to determine the best path for the robot to take, then tells the microcontroller how to drive the vehicle.

The vehicle was working well up until the day of competition, Linder said, when it developed several problems and could compete in only two of the nine runs.

"Our programs for navigation were working as expected, but the mechanical and electrical components were wearing out and failing on us," added Moua. "I would definitely try to use higher-rated components next time around."

Besides the technical skills they gained from the project, Linder and Moua reported learning much about teamwork, troubleshooting, perseverance, and creativity. In addition, they benefited from seeing other students' projects and getting ideas to improve their own design, they said.



2004 ITS Institute Outstanding Student of the Year Nathaniel Bird (left) with Institute director Max Donath at the awards ceremony in Washington, D.C.

Bird named Student of the Year

The 2004 ITS Institute Outstanding Student of the Year award was presented to Nathaniel Bird, a master's candidate in computer science at the University of Minnesota. Bird received his Bachelor of Science in Computer Engineering with high honors from Ohio Northern University, and is a registered Engineer in Training in the State of Ohio.

Bird has been a key asset to one of the Institute's high-profile research topics: monitoring human activities at bus stops, led by computer science professor Nikolaos Papanikolopoulos. Bird is currently working on developing automated intelligent vision-based traffic monitoring systems that can aid a human user in the process of risk detection and analysis. His work was applied to the problem of detecting drug-related activities at bus stops and received great reviews from the transit community.

Bird has shown excellence in the classroom by earning a 4.0 GPA as a graduate student. His current advisor describes him as "very well-organized and able to view a problem from several different perspectives without any difficulties." He has been involved in numerous honor societies, including the Tau Beta Pi Engineering Honor Society and the Sigma Pi Sigma Physics Honor Society. His classroom success has not only been recognized by being on the Dean's List at Ohio Northern University for each of his 12 semesters, but also by being awarded scholarships such as the Robert C. Byrd Scholarship from the Ohio Board of Regents and a University of Minnesota Computer Science fellowship.

In addition, Bird has been an author for multiple journals and conference papers and received a nomination for the best International Conference on Robotics and Automation (ICRA 2004) Vision Paper Award.

Advanced Transportation Technologies Seminar Series

This was the fourth year that the Institute sponsored its multidisciplinary seminar series at the University. These

Advanced Transportation Technologies Seminars included presentations by local and national researchers addressing diverse areas of ITS research, such as traffic management and modeling, human factors, sensing, intelligent vehicles, and social and economic policy issues as they relate to road- and transit-based transportation.

The seminars provide a way for students to learn about ITS technologies in areas outside their current field of study, for researchers to learn about other projects in progress, and for practitioners to learn about the technologies of the future.

The seminar series is available as a one-credit graduate-level course, or attendees can earn one professional development hour for each seminar. The series is also a required course in the Graduate Certificate Program in Transportation Studies at the University of Minnesota. Seminars are videotaped and available for loan by request; one presentation was also Web-streamed on the Internet.

The past year's presentations were:

- "Evacuation Planning," Qingsong Lu, Computer Science and Engineering
- "Maintaining Safe Headways While Driving," David Shinar, Industrial Engineering and Management, Ben Gurion University of the Negev, Israel
- "Inexpensive Attitude Determination Systems for UAV Applications," Demoz Gebre-Egziabher, Aerospace Engineering and Mechanics
- "Finding the Fountain of Youth for Snowplows and Other Fleet Assets," David Wyrick, Industrial Engineering, University of Minnesota Duluth
- "The Minnesota Comprehensive Highway Safety Plan," Bernie Arseneau, State Traffic Engineer, Minnesota Department of Transportation
- "Investing for Robustness and Reliability in Transportation Networks," David Levinson, Civil Engineering
- "Proactive Crash Prevention Solutions," John Hourdak, Civil Engineering

Student designs new system for snowplow blades

In April, mechanical engineering undergraduate student Michael Etheridge presented to University and Mn/DOT maintenance and research staff an innovative technique he developed for changing snowplow blades.

This new system, dubbed the Quick Edge Rapid Underbody Plow Cutting Edge Changing System, offers an alternative to the current system of replacing cutting edges on snowplows, which must be done frequently due to wear. Currently, these cutting edges are bolted to the plow blade with three or four fasteners—a process that is time consuming, tedious, and risky for mechanics doing the work due to the weight of the edges and the awkward positions staff must work in.

The system Etheridge proposed is designed to reduce the time and effort needed to replace cutting edges as well as the risk of personal injury. During his presentation, he discussed his design process, described the design features, and demonstrated a blade change with the prototype.

Etheridge began working on the project, which was initiated and sponsored by Mn/DOT, about a year ago as part of his honors program. Dr. Craig Shankwitz, Intelligent Vehicles program director, served as Etheridge's advisor on the project.

At the presentation, the system generated interest and enthusiasm from Mn/DOT personnel, several of whom remarked that they had not previously seen a design like it.

(The system was subsequently featured in the May 11 issue of Mn/DOT's weekly electronic newsletter, *Newsline*.)

The next step is to field-test the prototype on a maintenance truck in the fall, which will allow Etheridge to see how the design holds up, as well as get maintenance vehicle operators' opinions, he said.

Students gather for career expo

Approximately 80 college students from Minnesota and

Wisconsin gathered on campus in March for the 10th Annual Transportation Career Expo. The Institute partnered with CTS, the Minnesota Local Road Research Board, the Minnesota Local Technical Assistance Program, and the Women's Transportation Seminar to hold the event, which provided students an opportunity to ask questions, receive seasoned advice, obtain feedback on their resumes, and network



The 10th annual Transportation Career Expo brought together students and potential employers.

with more than 20 employers.

Employers promoted their organizations with booth displays, and several company representatives led informational sessions on transportation-related careers in areas such as intelligent transportation systems (ITS), engineering, policy and planning, and logistics management.

Huber Award goes to ITS students

The 2005 Matthew J. Huber Award for Excellence in Transportation Research and Education was given to



Student Michael Etheridge, far right, demonstrates the Quick Edge system he developed for Mn/DOT staff, left, and IV program director Craig Shankwitz, center.



CTS Assistant Director Cheri Marti, Nathaniel Bird, and Osama Masoud



Marti, Panos Michalopoulos, and Wu-Ping Xin

Wu-Ping Xin, a doctoral student advised by Panos Michalopoulos of the Department of Civil Engineering, and Nathaniel Bird, a master's candidate in computer science under Nikolaos Papanikolopoulos.

Praising Wu-Ping's interdisciplinary research approach, Michalopoulos said he agrees with Wu-Ping's philosophy: "He addresses a problem that is real and important, investigates the nature of the problem, then finds practical solutions." For example, Mn/DOT will shortly deploy a ramp-metering strategy for the metro freeway system that is based on Wu-Ping's modeling and analysis. Wu-Ping said he is very excited to contribute his work to the challenging field of ITS.

Research associate and former Huber winner Osama Masoud, who works with Papanikolopoulos, said Bird shows dedication and commitment in his work. "We rely on him to do a lot of the research, and he does a very good job." Bird's research, which involves video techniques to detect loiterers such as drug dealers at bus stops, arose from an idea by Metro Transit but has broader applicability for transportation security. "All researchers like to think their research is the most interesting in the world," he joked. "It's nice to get an award to confirm that your research is interesting and important."

Global Positioning System module released to Minnesota high schools

In an effort to educate high school students on the topic of ITS, the Institute developed a set of curriculum materials on the topic of Global Positioning Systems (GPS). The GPS Web module is a structured learning opportunity in

which high school students investigate the topic of GPS and its impact on travel. The students' assignment, while using the research cycle, is to search out information from given sources and demonstrate what they have learned.

The past year, the Institute gave travel awards to 13 University of Minnesota students so that they could attend and participate in various national conferences.

The GPS Web module was developed by the Institute's K-12 coordinator, Mark Tollefson, an area high school science teacher. A CD-ROM containing the module and a poster explaining ITS were distributed to 160 high schools around Minnesota. The Web module is also available on the Institute Web site at www.its.umn.edu/education/gps, making it available to educators and students around the world.

[edu/education/gps](http://www.its.umn.edu/education/gps), making it available to educators and students around the world.

Institute sponsors students to attend national conferences

The past year, the Institute gave travel awards to 13 University of Minnesota students (from both the Twin Cities and Duluth campuses) so that they could attend and participate in various national conferences. Students attending the National Rural ITS Conference in Duluth, Minn., were Wenling Chen, Paul Morris, Feng Qian, Jeffrey Sharkey, Lei Zhang, and Xi Zou.

Students who traveled to the national meeting of the Transportation Research Board (TRB) in Washington, D.C., were Baichun Feng, Vivek Deshpande, Lei Zhang, Nebiyou Tilahun, Feng Xie, Michael Corbett, Mathew Bevilacqua, and Nathaniel Bird.



Mats Sci



Technology Transfer

The Institute could not accomplish its goals without the transfer of its expertise and research results to local, national, and international audiences for use in real-world applications. Technology transfer also communicates to the world who we are, raising the profile of the Institute and its research, and serves to educate students, policymakers, and the general public about ITS issues and solutions.

Our efforts in this area are far-ranging in order to reach a broad and diverse audience of researchers, students, practitioners, policymakers, and others among the general public. Over the past year, we have provided tours and demonstrations of our research and facilities, sponsored seminars, published printed pieces, and maintained and updated our Web site. But perhaps the most direct method of transferring technology has been to send graduating students out into the workforce.

This section of the annual report highlights some of our technology transfer activities over the past year.

Lawmakers hear testimony about teen driving research

In January, ITS Institute director Max Donath testified before the Minnesota Senate Transportation Committee on teenage drivers and how ITS technology could play a role in improving their driving skills and reducing unsafe driving behavior.

Systems being evaluated by Institute researchers include seat belt and alcohol-based ignition interlocks that prevent operation of a vehicle, and methods for providing feedback on excessive speed or other unsafe operation as well as methods for logging these incidents for later analysis by parents or licensing officials.

Donath's presentation generated a number of questions from committee members related to privacy and who might have access to the data collected.

UMD researcher receives patent for visibility measurement system

In February, a visibility measurement system developed by Dr. Taek Kwon received approval for a patent (no. 6,853,453) from the U.S. Patent Office. Kwon, whose work has been sponsored by the Institute for the past few years, is a professor in UMD's Department of Electrical and Computer Engineering and a NATSRL researcher. Kwon's research resulted in a video-camera-based visibility measurement system that can provide automated measurements of atmospheric visibility in daylight and at night.

Kwon's system overcomes the disadvantages and limitations of prior technology by providing a system that can accurately measure atmospheric visibility similar to how the human eye perceives it. The system can also interface with existing equipment that is used for other purposes, such as a video camera, allowing additional verification of automatic visibility measurements made by the system.

Visibility is a critical piece of environmental information in promoting safe traffic operation. Kwon's system may be used to allow traffic managers to make safety-related decisions, such as whether or not to close roads, reduce speed limits, or warn motorists with the goal of preventing visibility-related crashes.

Institute research featured in national, local news

The ITS Institute is recognized as a national leader in ITS research, as evidenced by the media coverage it received during the past year.

Research led by Institute director Max Donath was featured in an article published by the *ITS Cooperative Deployment Network*. The article described the Institute's work on Intersection Decision Support (IDS) systems, which will improve safety at rural through-stop highway intersections by providing better information about oncoming traffic to drivers stopped on secondary roads.

"Looking out for Minnesota's Wooden Bridges" was

published in the August 19, 2004, issue of *UMNnews*, an electronic newsletter highlighting University work. The article described how researchers from NATSRL and UMD's Natural Resources Research Institute are working with the U.S. Department of Agriculture's Forest Service and county road departments to use innovative sensing technologies to save wooden bridges from rotting—a project funded through the ITS Institute. Researcher Brian Brashaw organized what was learned into training courses for Minnesota Department of Transportation (Mn/DOT) field inspectors and Minnesota county highway department inspectors. So far, more than 250 engineers and inspectors have been trained.

After heavy fog caused a multi-vehicle crash in Duluth, Minn., last winter, the local NBC television news affiliate highlighted UMD researcher Taek Kwon's work on trying to identify when and where fog might develop, for which no system currently exists. This capability could allow Mn/DOT to post appropriate warnings for drivers and head off potential pileups.

The University of Minnesota's student-run newspaper, the *Minnesota Daily*, ran a feature of the Twin Cities team that built a vehicle and competed in the Intelligent Ground Vehicle Competition.

Finally, HumanFIRST research on driver distraction was featured in an article in the St. Paul *Pioneer Press* and in segments airing on Minnesota Public Radio's *All Things Considered* and the local FOX television news affiliate. The research, conducted by HumanFirst director Nic Ward and research associate Mick Rakauskas, found that drivers in the simulator who were legally drunk often performed better than sober drivers who were talking on their cell phones or operating the car radio. Rakauskas was interviewed at length for the segments.



Visibility targets, part of Taek Kwon's patented system, along Highway 35 near Duluth, Minn.

Rural safety meeting highlights technology-based solutions

In Minnesota, more than two-thirds of traffic fatalities occur in rural areas. Two Institute researchers shared how technology holds promise to reduce these tragic numbers at a special briefing held in March for U.S. Representative James Oberstar.

Those attending the event, held in Cambridge, Minn., represented Mn/DOT, the Cambridge city council, Isanti County, two local Toward Zero Deaths community groups, and other area organizations.

Institute director and professor Max Donath discussed research that focuses on how technology at unsignalized intersections can help drivers waiting to cross or merge onto a busy rural highway decide if the gap before an oncoming vehicle is large enough to proceed safely.

This intersection decision support (IDS) technology—made up of wireless communications and roadside radar units—works in ground fog and other low-visibility conditions. In their work, researchers are using an instrumented rural intersection south of the Twin Cities (see www.its.umn.edu/research), along with a driving simulator on the Minneapolis campus to test systems under more structured conditions.

Thomas Horan, research fellow at the University's Humphrey Institute of Public Affairs, then discussed the role of technology in responding to rural crashes. The good news,

he said, is that cell phone use and the related rise in communications mean more data are available; the bad news is the demand this places on dispatch systems. Minutes matter in emergency response, but calls must travel through an array of agencies, from 911 to dispatch to fire department and hospital. Horan's research looks at how technology can

improve end performance. "Using technology to respond in rural areas should be a top transportation, health, and economic priority," Horan concluded.

Institute highlighted as Minnesota hosts rural ITS conference

Seventy-five speakers from across the nation discussed the latest technological solutions to rural multimodal transportation challenges at the 2004 National Rural ITS Conference, held in August 2004 in Duluth, Minn. The nearly 350 attendees heard

presentations on a wide range of ITS applications—including Institute research—and toured research facilities.

The conference was sponsored by ITS Minnesota (the state chapter of the Intelligent Transportation Society of America), with the assistance of ITS America, the U.S. Department of Transportation, the Minnesota Department of Transportation, the Center for Transportation Studies, and the ITS Institute.

One of the conference sessions, "Rural Intersection Collision Avoidance," featured presentations by Institute researchers on the intersection decision support research program. Craig Shankwitz, Intelligent Vehicles program director, presented "Assisting the Driver at Rural Intersec-



The IDS research project uses roadside radar units installed along a rural two-lane highway in southern Minnesota.

tions,” and Max Donath, ITS Institute director, presented “Human Factors: Communicating to the Driver When to Enter the Intersection.”

The program’s technical tours included Northland Advanced Transportation Systems Research Laboratories (NATSRL), located at the University of Minnesota Duluth. NATSRL staff also provided a tour of their Cloquet, Minn., research facility and demonstrated the data acquisition capabilities from their on-site sensors.

Institute researchers discuss driving behavior at traffic safety conference

Institute researchers presented a concurrent session at the Toward Zero Deaths: Integrating Minnesota’s Traffic Safety Agenda Conference, held in September 2004 in St. Cloud, Minn. The conference, which drew about 450 attendees, served as a forum on how to reduce the number of fatalities and injuries on Minnesota roads.

Janet Creaser, with the University’s HumanFIRST program, and Kathleen Harder, with the University’s Center for Sustainable Building Research, provided insights into driver behaviors and ideas on how to best deal with these from a human factors standpoint.

Creaser discussed the various characteristics of younger and older drivers. In both of these “at-risk” groups, there are several factors that, combined and individually, increase the number of fatalities in each of these groups. She explained how appropriate types of traffic and vehicle engineering, education, enforcement and licensing, and ITS can all be used to mitigate the risks of drivers in these two age groups.

Harder reported that driver aggression (separate from road rage) is a major threat to safety in roadway environments. She explained that there might be ways to alter the driving environment to change the behavior of people who are tripped into aggressive behavior. This could be done, she said, by designing roads that include traffic calming features, providing travel time information via changeable

message signs, creating better roadway signage, and developing various mass transit options.

USDOT reps make site visit

In April, the Institute hosted three representatives from the USDOT’s Research and Innovative Technologies Administration for a day of meetings with staff, tours, and demonstrations. Robin Klein, university program specialist, Amy Sterns, university program specialist with the RITA Office of Research, Development, and Technology, and Ron Boenau, division chief of Advanced Public Transportation Systems, Federal Transit Administration, visited the Institute to see and learn about its work and operation.

Institute director Max Donath kicked off the day’s activities by giving an overview of the Institute’s management structure as well as examples of partnerships it has developed. Robert Johns, director of the Center for Transportation Studies, spoke about the organizational structure of CTS and its relationship with the Institute. Gina Baas, manager of outreach and education services, addressed technology transfer activities, and Dawn Spanhake, manager of research development and contract coordination, discussed education efforts and research highlights. Professor Nikos Papanikolopoulos with the Computer Science and Engineering Department spoke on his ITS-related research on vision-based techniques for computerized monitoring of human activity in public spaces. Finally, tours and demonstrations were given of their respective programs by ITS Lab manager Ted Morris, Intelligent Vehicles program director Craig Shankwitz, and HumanFIRST program director Nic Ward.

Institute director discusses technology’s role in transportation financing

Regional and national transportation officials, policymakers, and professionals joined U.S. Representative James L. Oberstar April 17–18 to discuss the future of transportation finance, especially alternatives to the gas tax in anticipation



Kathleen Harder (left) and Janet Creaser presenting at the TZD conference



Harlan Stech, grad students Joe Erickson and Fenghuah Wang, and Guihua Fei at the NATSRL program's Research Day in Duluth

for the day when gasoline is no longer the dominant fuel source for vehicles.

Among other speakers at this fourth annual Oberstar Forum, Institute director Max Donath discussed potential methods of charging users based on how much they drive. "There are technologies available...such that we can distinguish individual roads and allow each jurisdiction to recoup the cost of travel on its roads," he said. These technologies include differential global positioning systems and digital maps, which could offer high enough accuracy to track vehicles as they move back and forth between a high-occupancy toll lane and a normal lane and apply road-use pricing accordingly.

Civil engineering assistant professor David Levinson described his research on the future of transportation networks and their financing, and Lee Munnich, director of the Humphrey Institute's State and Local Policy Program, emphasized the need for political leaders to advocate for necessary changes.

Transportation research highlighted at annual events

University of Minnesota researchers from the Duluth and Twin Cities campuses shared their research findings with practitioners, policymakers, department of transportation staff, and other researchers at annual research events that drew attendees from across the state and region.

UMD researchers and their work were featured at the Northland Advanced Transportation Systems Research Laboratories (NATSRL) third annual Research Day, held November 4 at Mn/DOT District 1 Headquarters in Duluth.

Among the presenters were Stanley Burns, Richard Maclin, Taek Kwon, David Wyrick, Harlan Stech, and Emmanuel Enemuoh, who discussed topics ranging from traffic data warehousing to determining the most cost-effective life cycle for fleet assets in the Mn/DOT inventory. In addition, many of the students and researchers involved in the

program presented poster sessions, during which they gave updates and answered questions on their specific project roles, along with the status of their findings.

In April, several ITS Institute researchers discussed their work at the Center for Transportation Studies 16th Annual Transportation Research Conference in St. Paul. Human-FIRST research scientist Mick Rakauskas presented the findings from a study assessing the risk of cell phone use compared to commonly accepted in-vehicle tasks, as well as driving while intoxicated—a topic that immediately generated media interest. John Bloomfield and Kathleen Harder discussed their research in the area of driver impairment as well. Nikos Papanikolopoulos presented his research on computer vision-based methods for data collection at traffic intersections, and Jiann-Shiou Yang, with UMD's NATSRL, discussed special events travel-time prediction based on Kalman filtering.

Visiting researchers help foster strategic partnerships

During the past year, the Institute continued to work with visiting researchers and instructors.

The Advanced Transportation Technologies Seminar Series provided an opportunity to host Dr. David Shinar from the Industrial Engineering and Management Department at the Ben Gurion University of the Negev in Israel. Shinar spoke to the Institute on his current research, which is investigating how drivers maintain safe headways and how headway skills could be improved.

Dr. Thomas Horan, an associate professor at Claremont Graduate University and visiting scholar at the Humphrey Institute of Public Affairs, is part of the Sustainable Technologies Applied Research (STAR) Initiative. Horan is doing research on wireless EMS and telecommunication network planning and access in a rural context.

Other visiting researchers, all working with the Institute's HumanFIRST Program, include Nobuyuki Kuge of Nissan, Erwin Boer of the University of California, Jeff Caird of the

University of Calgary, Andras Kemeny of the College de France, Jason Laberge of Honeywell, and Dick de Waard of the University of Groningen.

Communications promote Institute work

The Institute's electronic and printed communications continue to improve and evolve in order to better publicize Institute work and serve those looking for information. Staff completed the changeover to a database-driven system for publishing information on research projects. The transition to this system enables more rapid and accurate publication of the latest information on all ITS Institute research projects, as well as a greater variety of options for searching and displaying information. The new Web pages draw content directly from the research database at the Center for Transportation Studies.

Institute Web pages providing information on intersection decision support pooled-fund research projects (www.its.umn.edu/research/applications/ids) were praised as "a model for other lead agencies to follow" by the FHWA's Transportation Pooled Fund manager working with the projects. The Web pages are used by pooled-fund participants to share information and presentation materials related to the project and to get updates on research progress.

The Web site continued to provide electronic distribution for Institute news, including the *Sensor* newsletter and articles covering research projects and seminars by faculty and visiting researchers.

On the print side, the fifth ITS Institute annual report, with photos and coverage of researchers, their students, and their projects, was published. Printed copies of the annual report were mailed to nearly 1,700 individuals (an increase of about 13 percent over last year), as well as distributed at TRB, the ITS America Annual Meeting, and other Institute-related events. In addition, the report was again made available as a PDF file for download from the Institute's Web site.

Circulation of the ITS Institute's *Sensor* newsletter in-

creased slightly to around 2,300. The *Sensor* is one of the primary vehicles for increasing visibility of the ITS Institute, and its high circulation represents a wide interest in ITS research activities among academic and professional audiences. Subscriptions to the *Sensor* can now be requested online at www.its.umn.edu/publications/subscriptions/index.html.

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